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Computer Graphics & Interactive Techniques

SQuadGen

Generating Simple Quad Layouts via Chart Distance Fields

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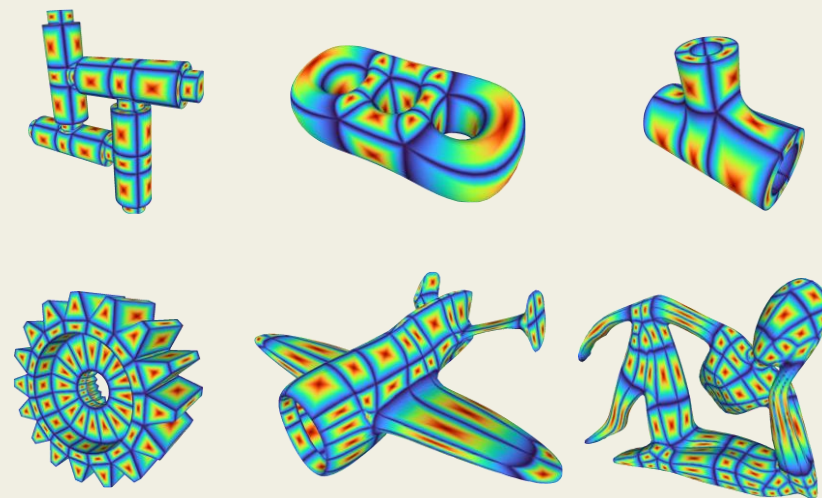


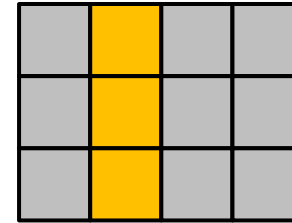
Chart Distance Field (CDF) Visualization



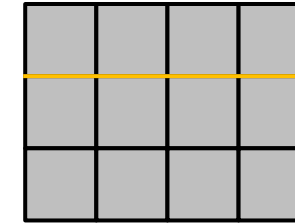
What Artists Want: Easily Editable Layouts



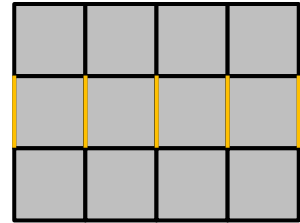
- “Artist-like” mesh → vague
- Real Goal: **Editability**
- How 3D artists work?
 - Select & Edit with loop tools: *vertex loops* • *edge loops* • *face loops* • *edge rings*
 - Loop tools work conveniently when the layout is **Simple**
 - Intuitive meaning of Simple:
 - **A clean loop goes around once — no spiral, no self-crossing**
 - **Underlying mesh — full-quadrilateral / quad-dominant meshes**
 - Messy layout: loops break down, editing become painful



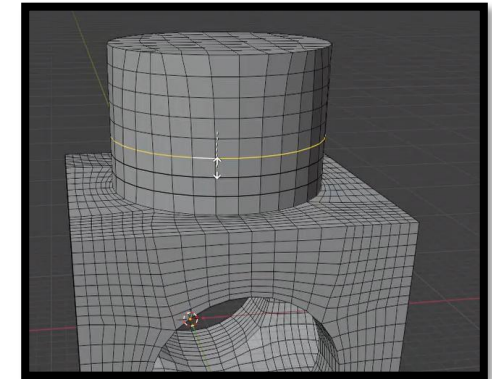
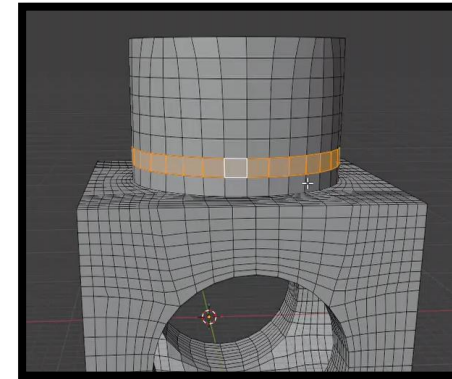
Face loop



edge loop



edge ring



Loop Simplicity of Quad Layouts

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- **Common Metrics**

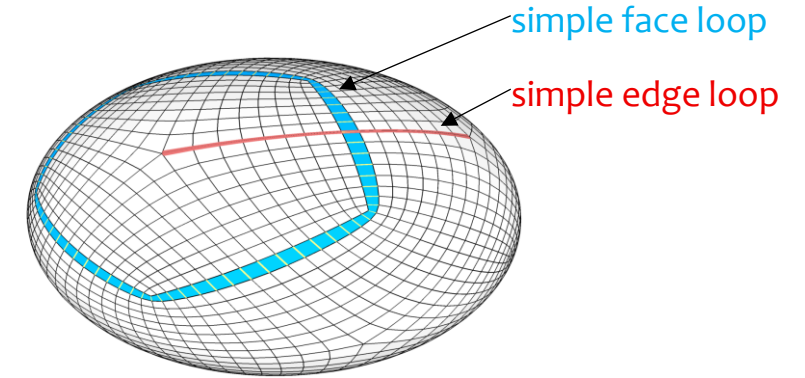
- Fewer charts N_c , Fewer irregular vertices N_I
- Useful, but not enough — **they don't tell if a loop is easy to edit**

- **Our Metric: Loop Simplicity** (S_{fl} for face loop, S_{el} for edge loop)

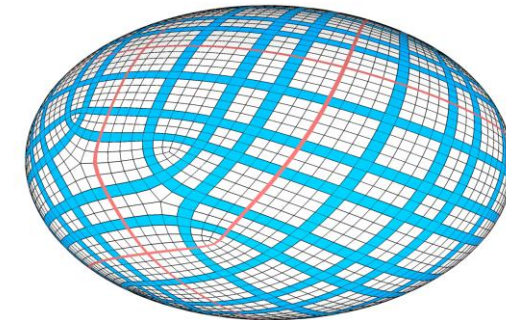
- A loop is **SIMPLE** if no spiral and cross itself
- **Face/Edge Loop simplicity** of a quad mesh: **area ratio covered by simple loops**
- **1 is the best, 0 is the worst**

- **Overall Loop Simplicity of a Quad Mesh:**

$$S_l = \min(S_{fl}, S_{el})$$



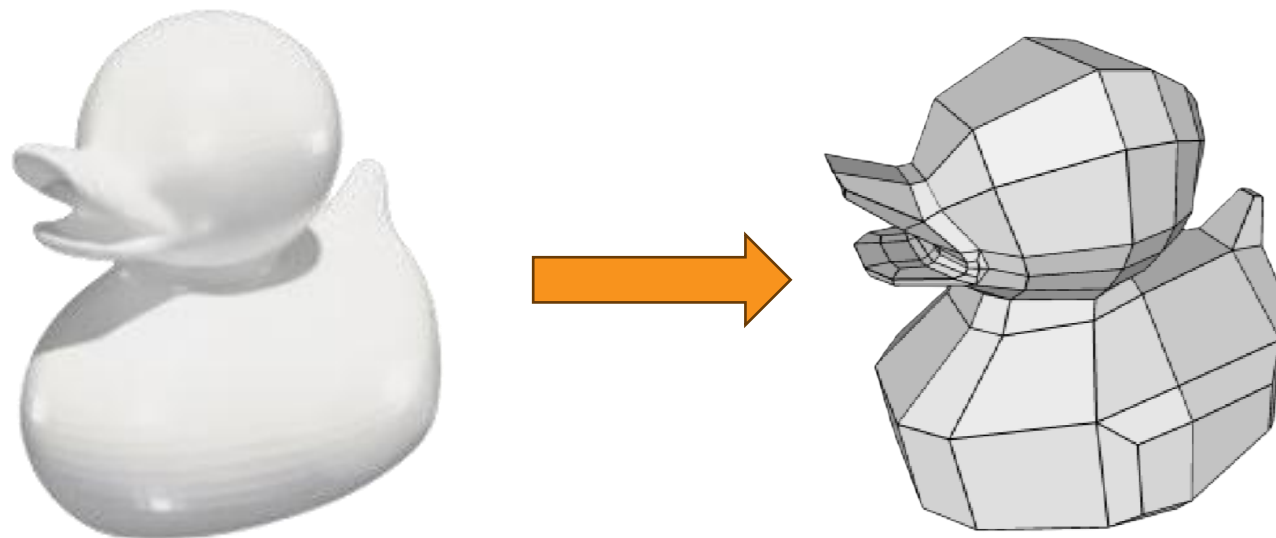
$$S_{fl} = S_{el} = 1, N_c = 60$$



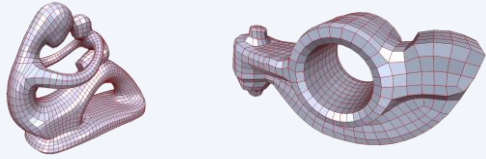
spiral,
self-crossing
face/edge loop

$$S_{fl} = 0, S_{el} = 0.093, N_c = 436$$

Our Goal: Simple Quad Layout Generation



**Given a 3D surface, generate a quad mesh
with simple, easily-editable layout !**



Quad Remeshing

Directional/cross/frame fields [Kalberer et al. 2007, Bommes et al. 2013, Campen et al. 2015, etc.]

Focus: field smoothness, field integrability, feature preservation

It is hard for integer optimization to ensure global simplicity

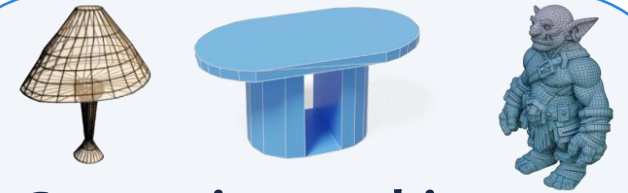


Layout simplification

Dual Loop [Campen et al. 2012], Graph Optimization [Tarini et al. 2011, Bommes et al. 2011, Couplet et al. 2021, etc.]

Focus: reduce irregularities

It depends on good starting layout.



Generative meshing

PolyGen [Nash et al. 2020], MeshGPT [Siddiqui et al. 2024], SpaceMesh [Shen et al. 2024], QuadGPT [Liu et al. 2026], etc.

Methodology: Directly predict discrete mesh topology
Sequentially, not holistic

It doesn't aware simplicity, hard to stay manifold.

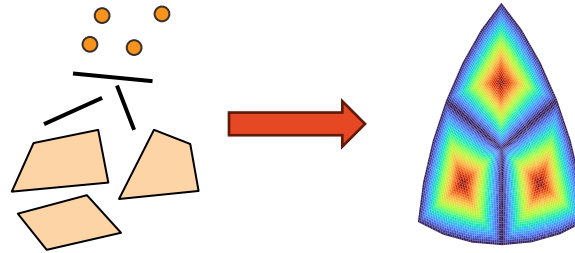
Our Key Idea

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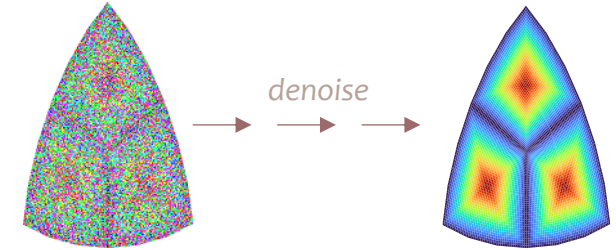
Learning perspective

Learn from **artist-created quad layouts** to match artists' preference



Representation Perspective

Treat layout generation as **continuous field** synthesis, NOT next token (vertex/face) prediction.



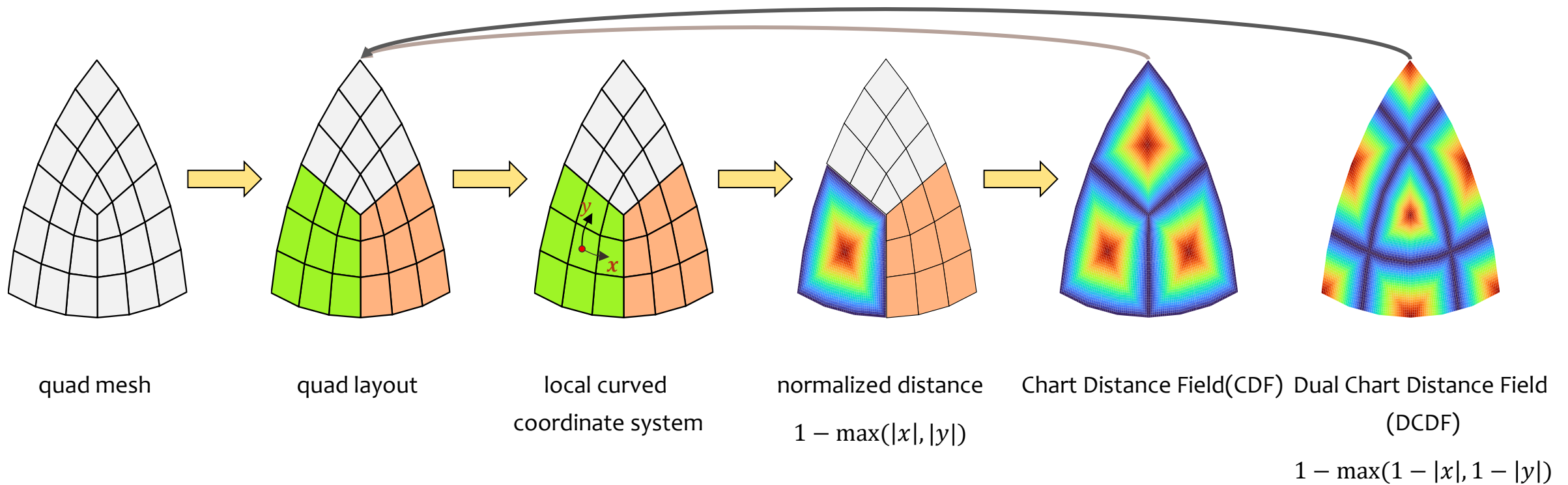
Generative Perspective

Diffusion models excel at smooth signals: generate the field first, then read the quad layout out of it.

Representation: Chart Distance Fields (CDF)



- **Chart Distance Field:** Representing Quad Layouts as Continuous Scale Fields over Surfaces.



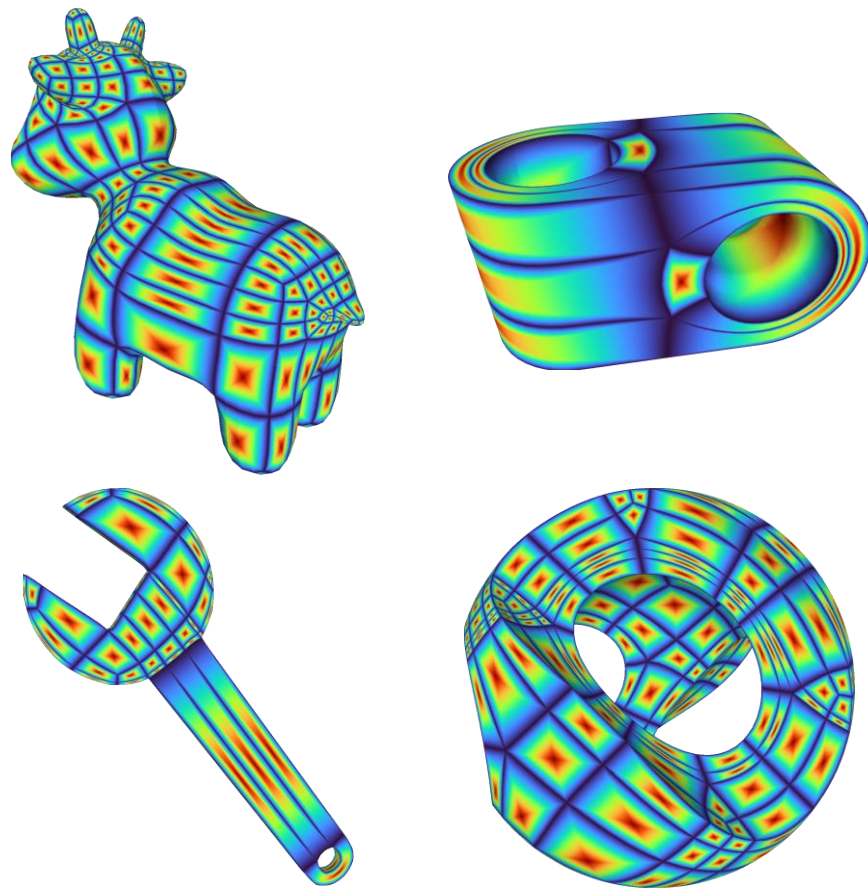
Please refer to the paper for details.

Examples: CDF & DCDF

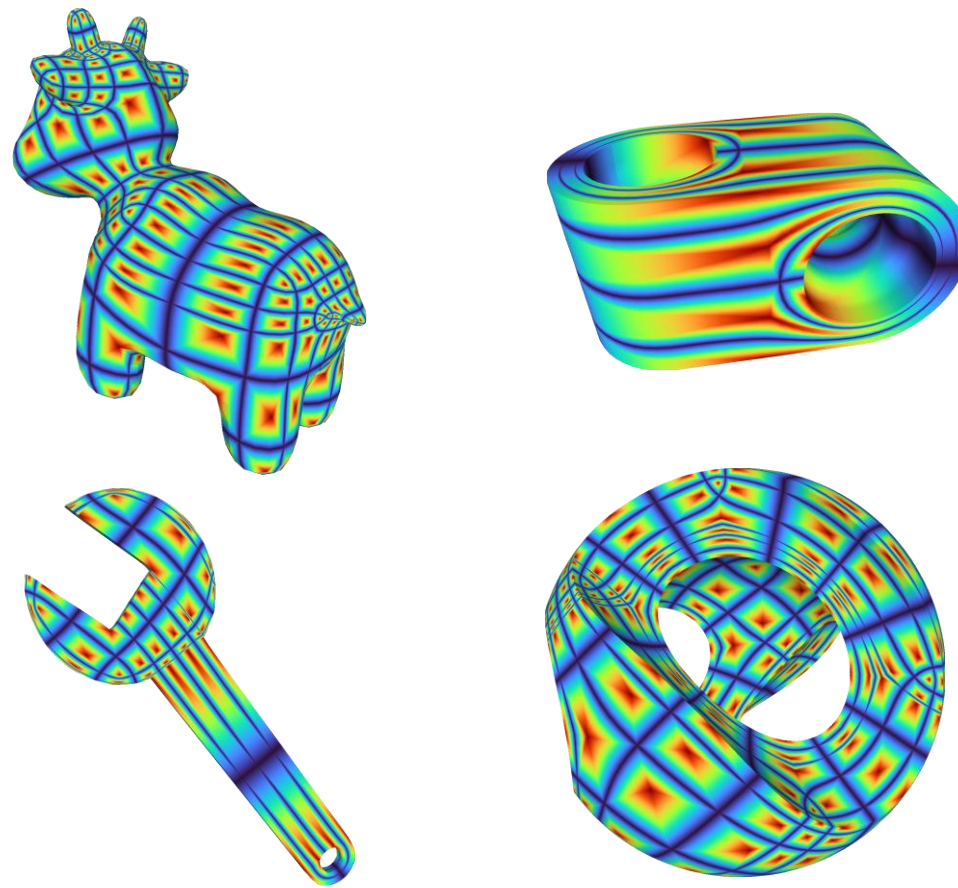
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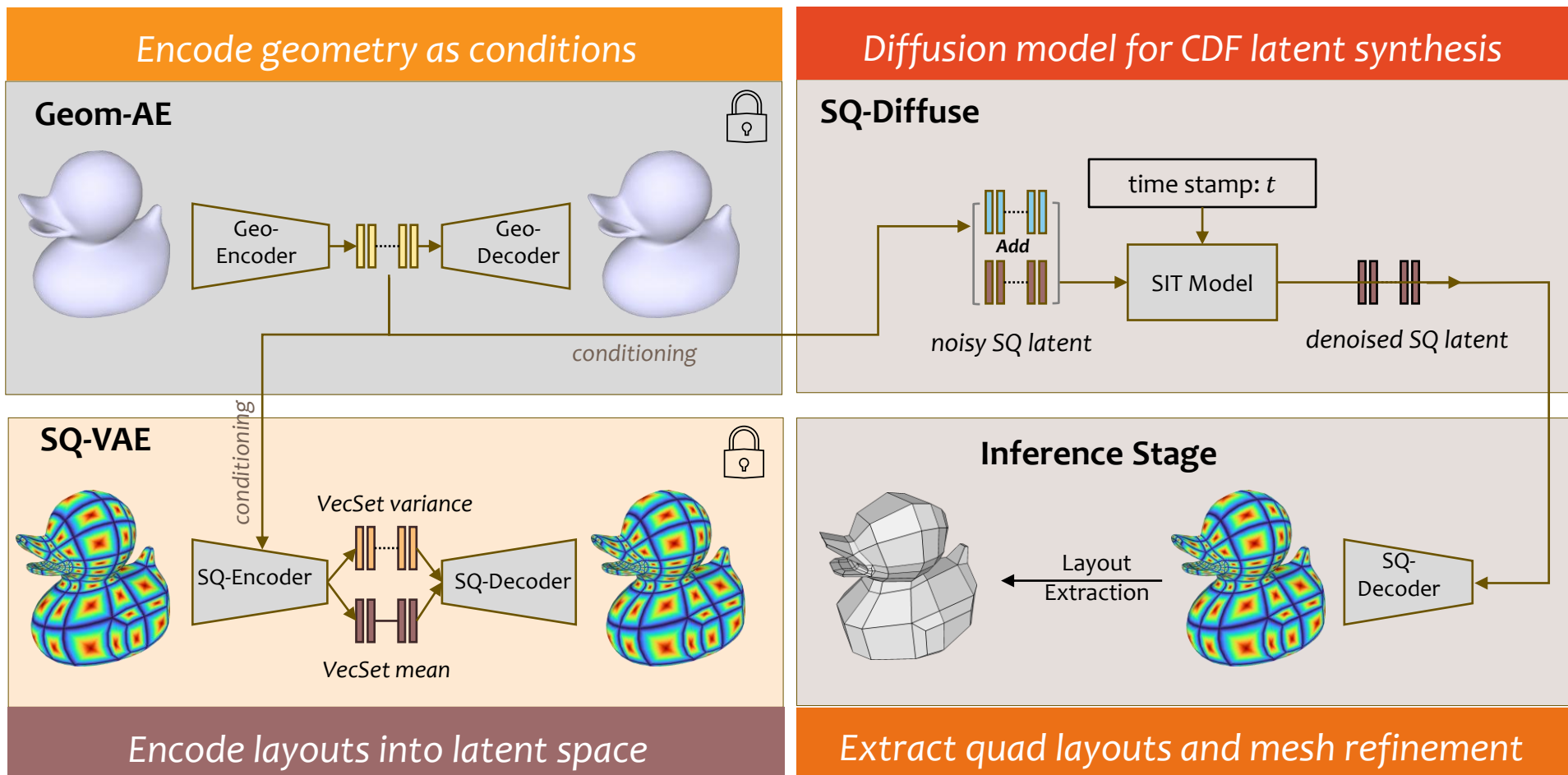
Chart Distance Fields

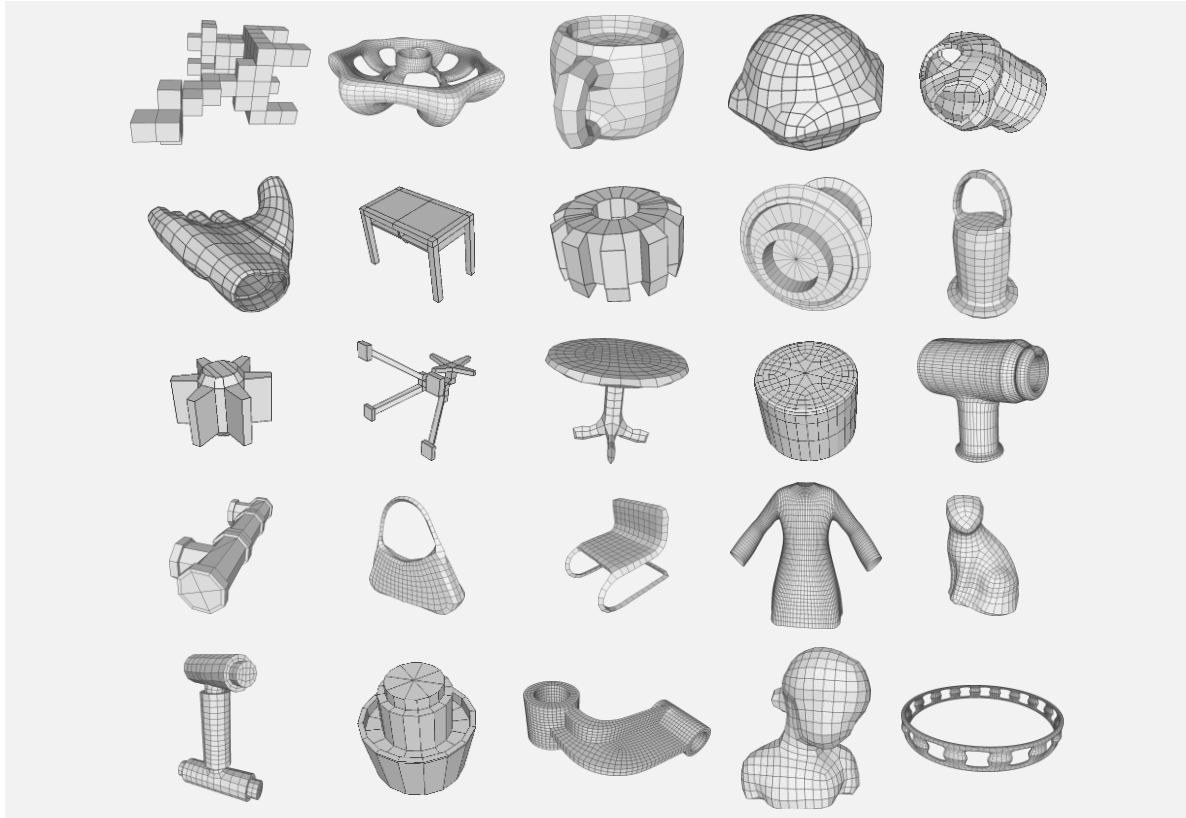


Dual Chart Distance Fields



SQuadGen: Learn and Synthesize CDFs via Latent Diffusion Models





Samples of curated data

DATA CREATION

- **Large data source:** Objaverse
 - created by artists; original quad-dominant layouts are missing
- **Loop-aware triangle merging algorithm**
 - Recover all-quad meshes
- **Recovered quad layouts**
 - 1.6 million single-connected quad meshes
- **Curated simple quad layouts: 230k**
 - filtering via loop simplicity scores (>0.618) and other criteria

Experimental Setup & Performance

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EVALUATION SETUP

- **Test sets:**
 - Part1k (in-domain) : 1k held-out data w/GT.*
 - ABC1k (out-of-domain): 1k CAD shapes, no GT.*
 - Model300 (stress test): 300 shapes with varied complexity*
- **Evaluation metrics:**
 - Loop Simplicity S_l , Complex Num N_c

Highest simplicity score
~10x fewer quad charts.

Dataset	Method	$\uparrow$	$S_l \uparrow$	$N_c \downarrow$
Part1k	Ground-Truth		1.00	23.33
	QuadriFlow		0.55	1645.69
	QuadWild		0.86	127.21
	QuadRemesher		0.82	558.83
	FSCP		0.79	685.15
	SQUADGEN		0.95	47.65
ABC1k	QuadriFlow		0.26	2468.44
	QuadWild		0.64	5057.44
	QuadRemesher		0.69	2887.89
	FSCP		0.61	4074.68
	SQUADGEN		0.78	216.73
Model300	QuadriFlow		0.14	3106.90
	QuadWild		0.38	9032.79
	QuadRemesher		0.37	7637.73
	FSCP		0.31	6626.65
	SQUADGEN		0.48	670.77

Visual Comparison (cont.)

Random color per chart — fewer & larger ~ simpler

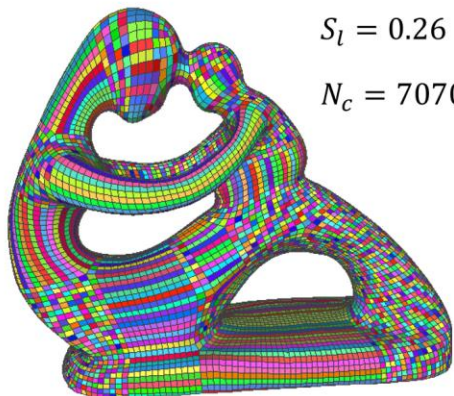
S_l - Loop simplicity

N_c - # Charts



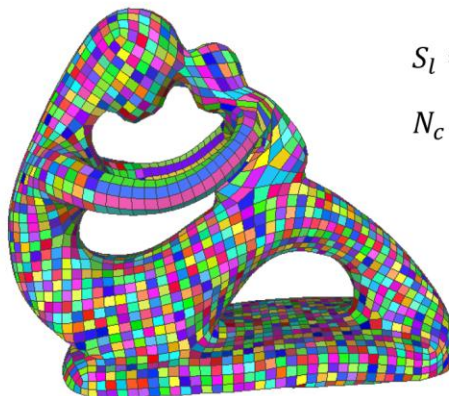
QuadWild

$S_l = 0.26$
 $N_c = 7070$



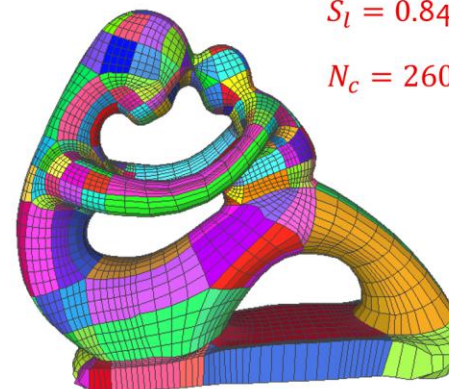
QuadriFlow

$S_l = 0.03$
 $N_c = 3910$

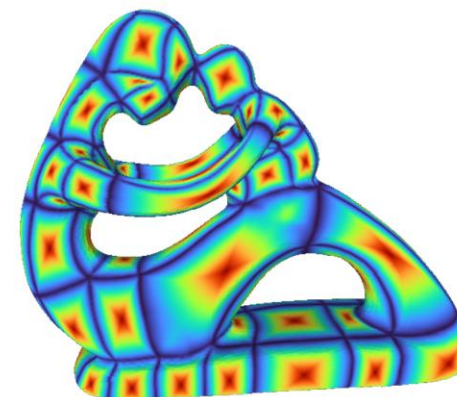


Ours

$S_l = 0.84$
 $N_c = 260$

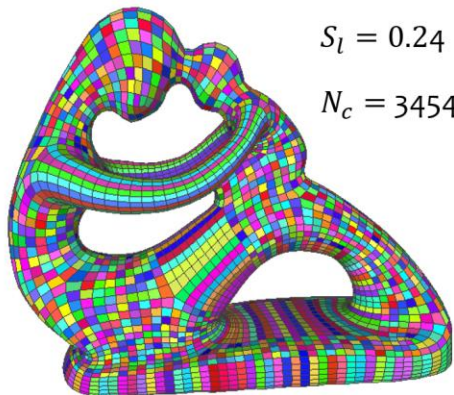


Synthesized CDF



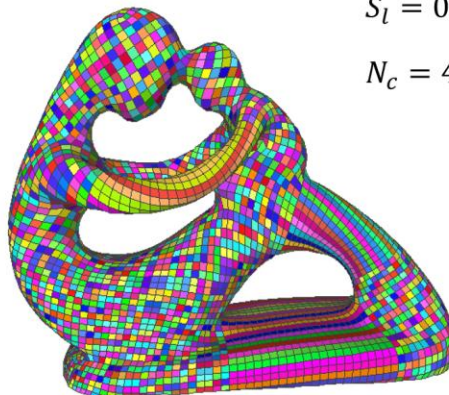
QuadRemesher

$S_l = 0.24$
 $N_c = 3454$

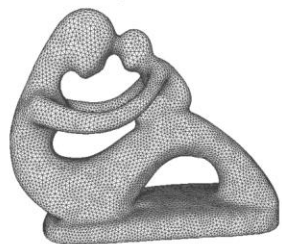


FSCP

$S_l = 0.15$
 $N_c = 4328$



Input

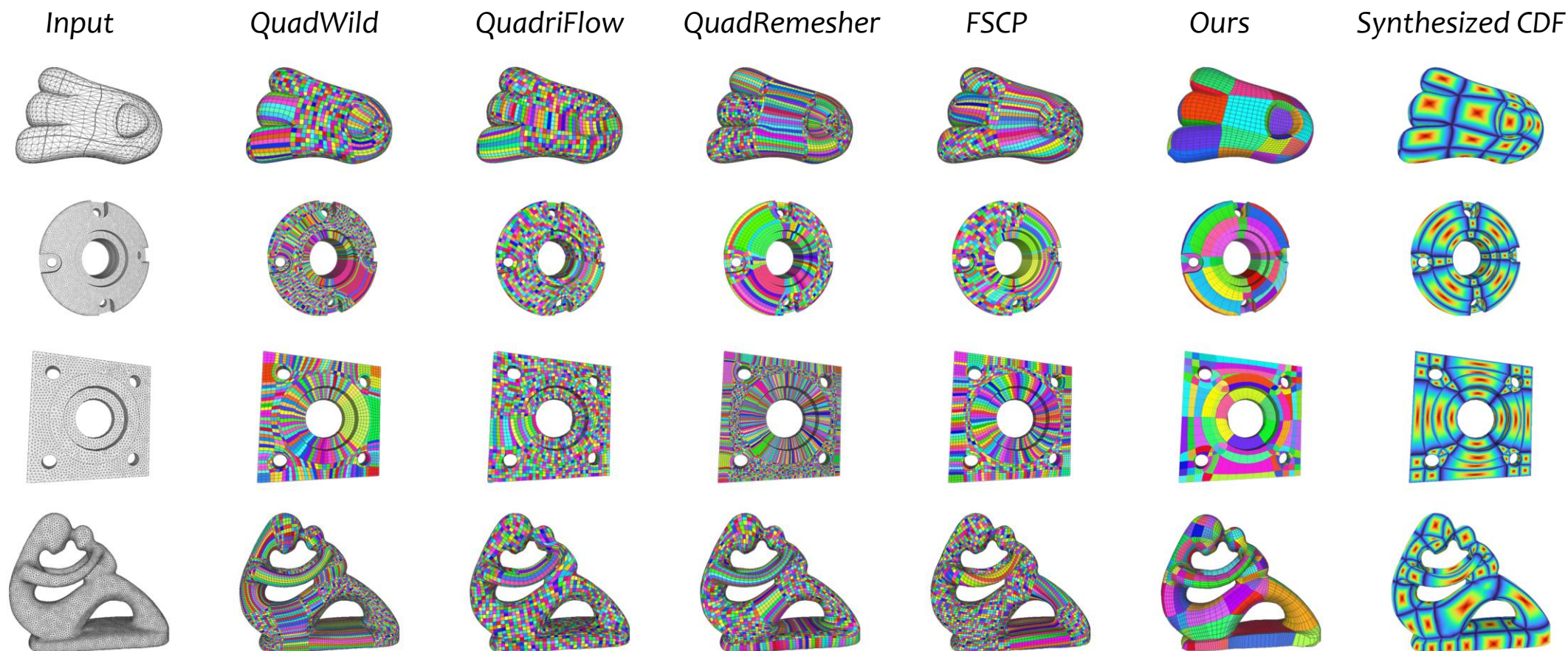


Ours produces the **simplest** layouts
with **far fewer** charts.

Visual Comparison

Random color per chart — fewer & larger ~ simpler

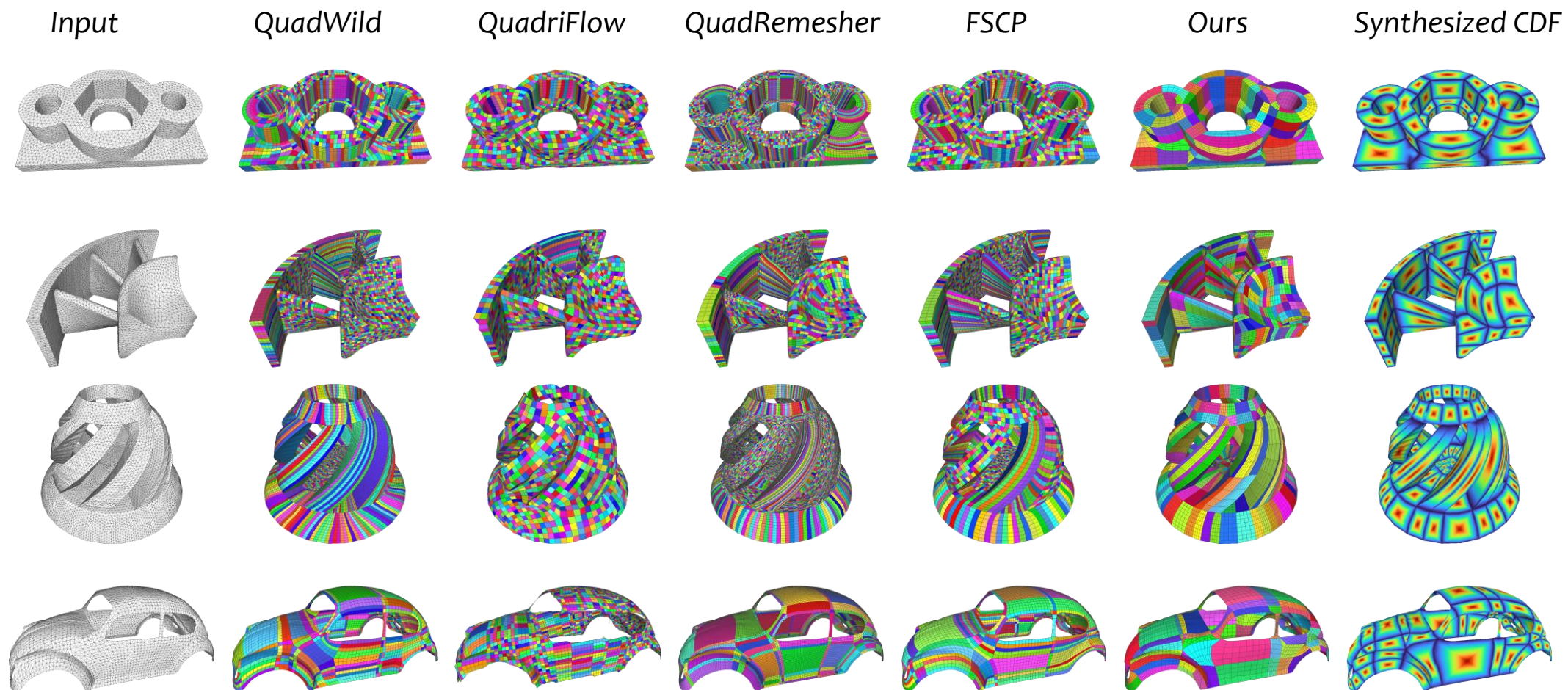
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Visual Comparison (cont.)

Random color per chart — fewer & larger ~ simpler

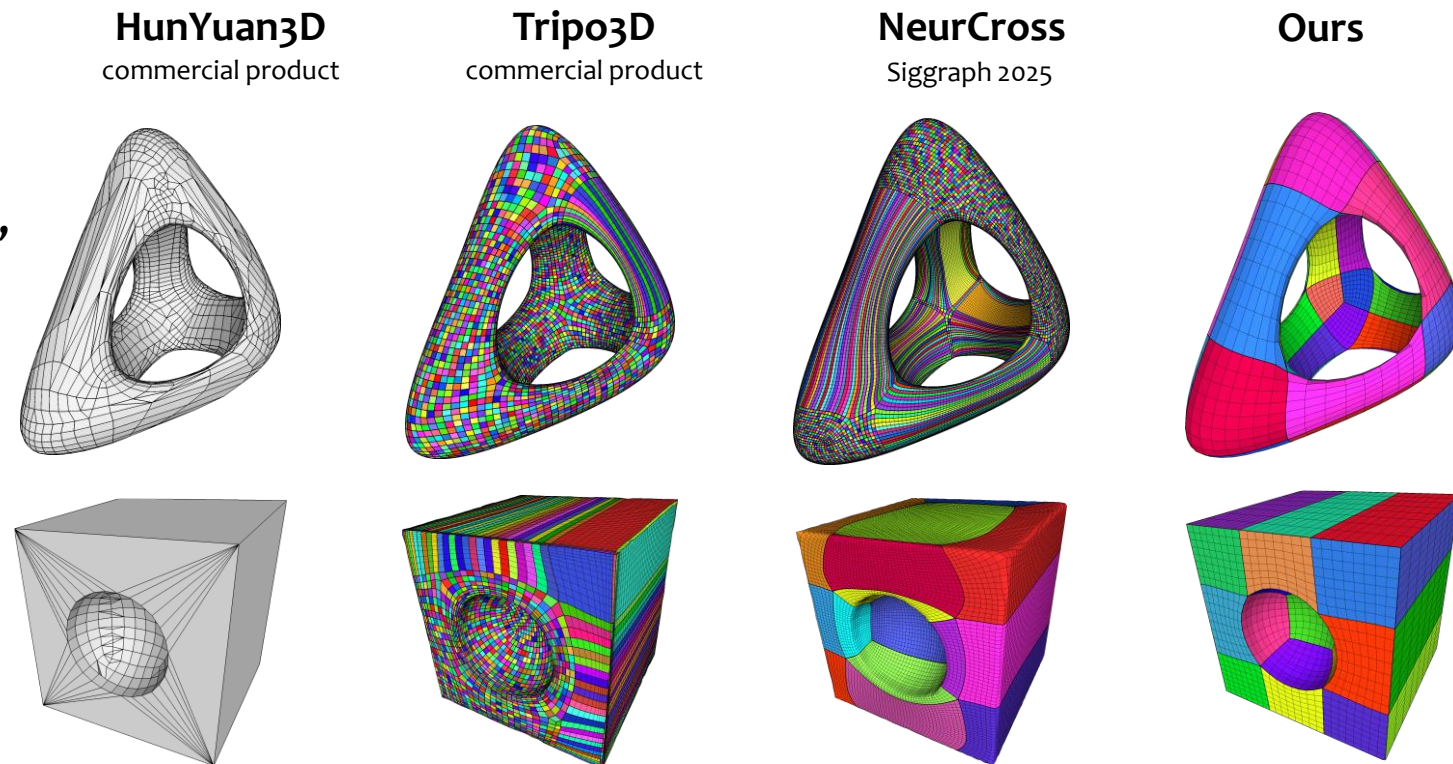
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Comparison with Learning-based Low-Poly & Quad Meshing Approaches

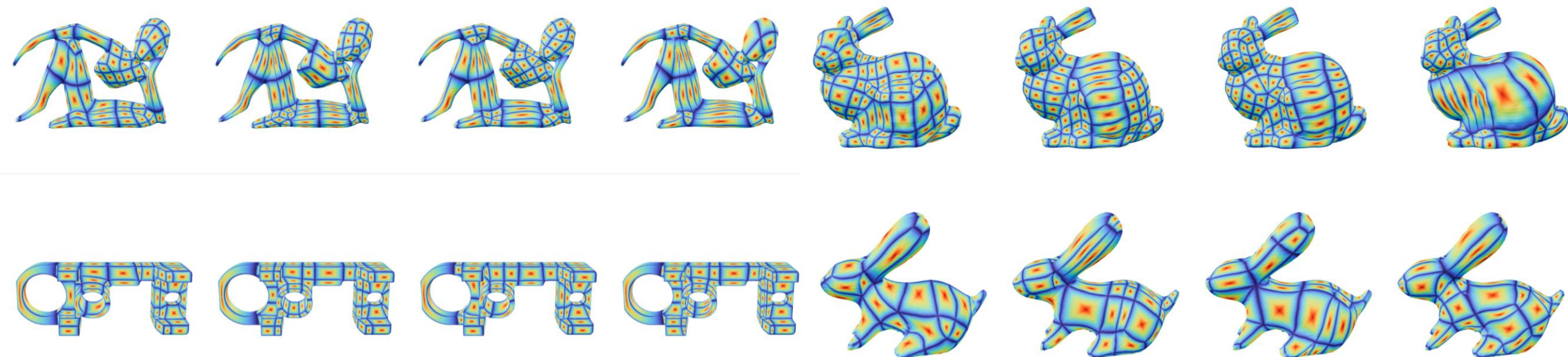


- **HunYuan3D:** Triangle & more irregularities
- **Tripo3D & NeurCross:** many spiral loops & charts, sharp features missing
- **Ours:** simple layout & feature preserving



Diverse Generated Results

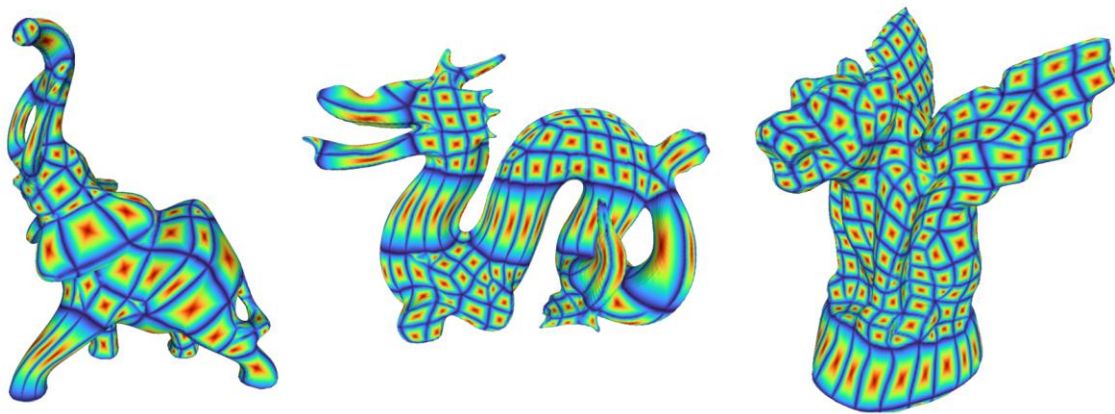
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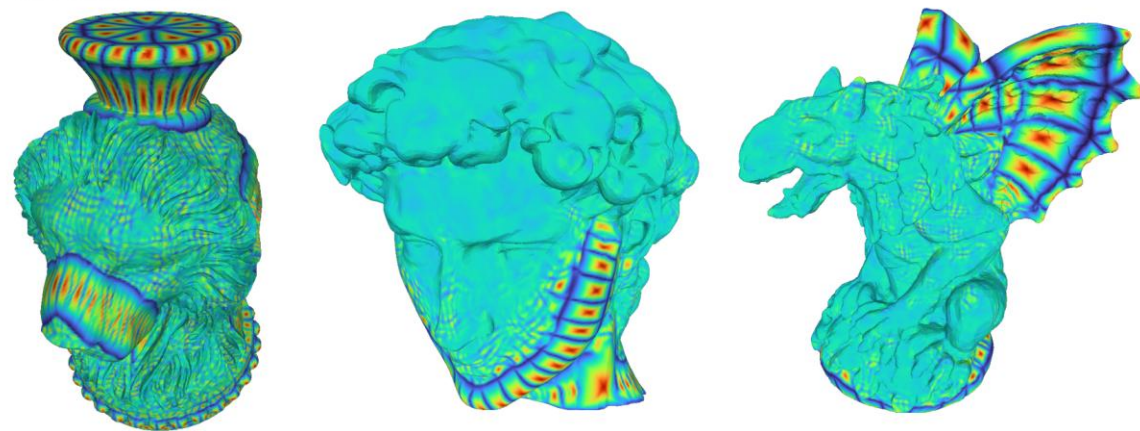
GENERALIZABILITY

- Generalizes well on out-of-distribution but smooth shapes



FAILURE EXAMPLES

- Fail on shapes with fine details (unseen in training) → invalid CDFs



Take-Home Message

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- **Goal:** generate a clean and simple layout for editing.
- **Representation: Chart Distance Field** — *easy-to-learn continuous fields for quad layout generation*
- **Loop Simplicity:** Loop-editing-aware metric
- **Dataset — 230k simple quad layouts:** diverse, large-scale, high loop simplicity scores.
- **SQuadGen:** Diffusion model to generate CDFs and yield simple and editable quad layouts.
- **Code & Model:** To be released, currently undergoing the release approval process.



[Project page](#)

