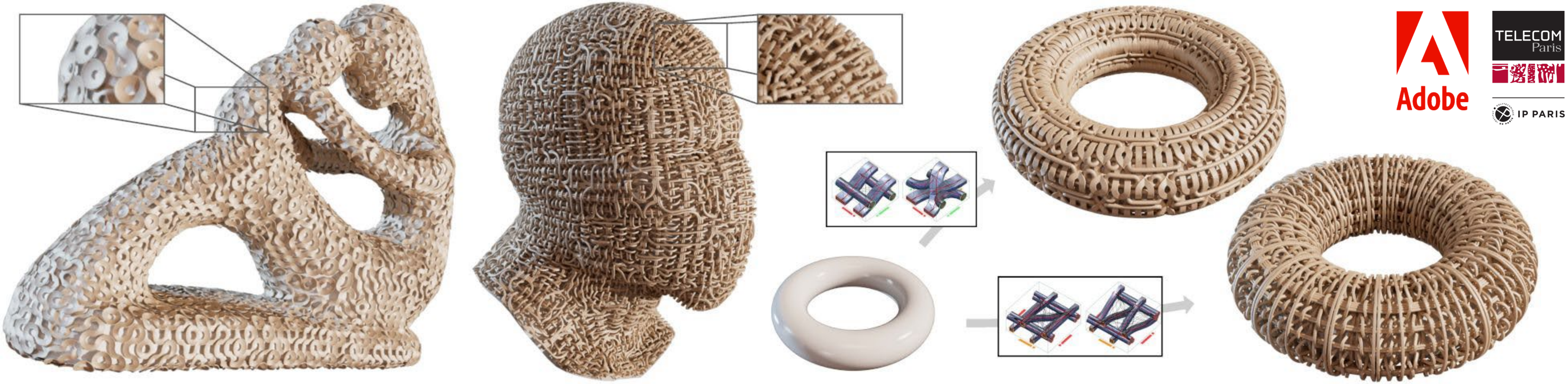

MESOGEN

DESIGNING PROCEDURAL ON-SURFACE STRANDED MESOSTRUCTURES

ÉLIE MICHEL & TAMY BOUBEKEUR

MESOSTRUCTURE

- **Geometry** representation & authoring process depends on the **scale**.

MESOSTRUCTURE

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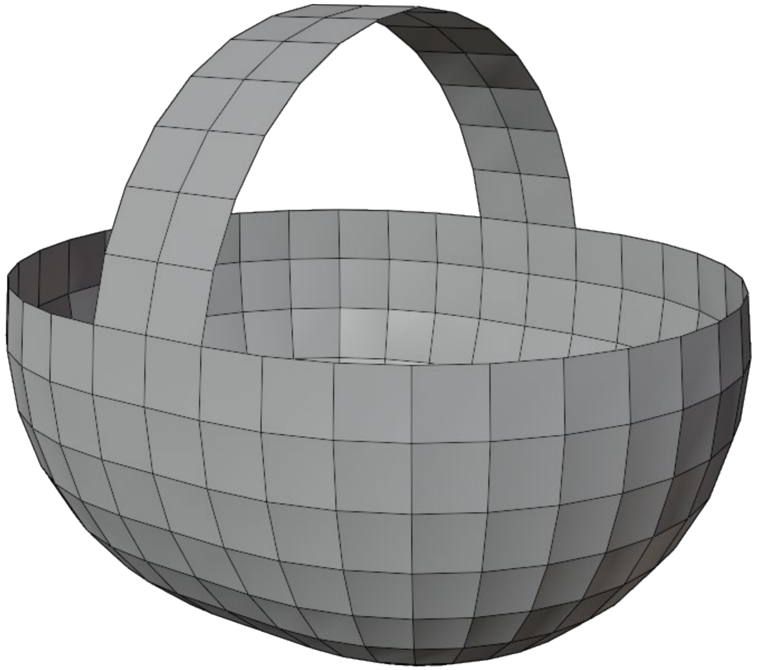

MACRO

3D MESH

MESOSTRUCTURE

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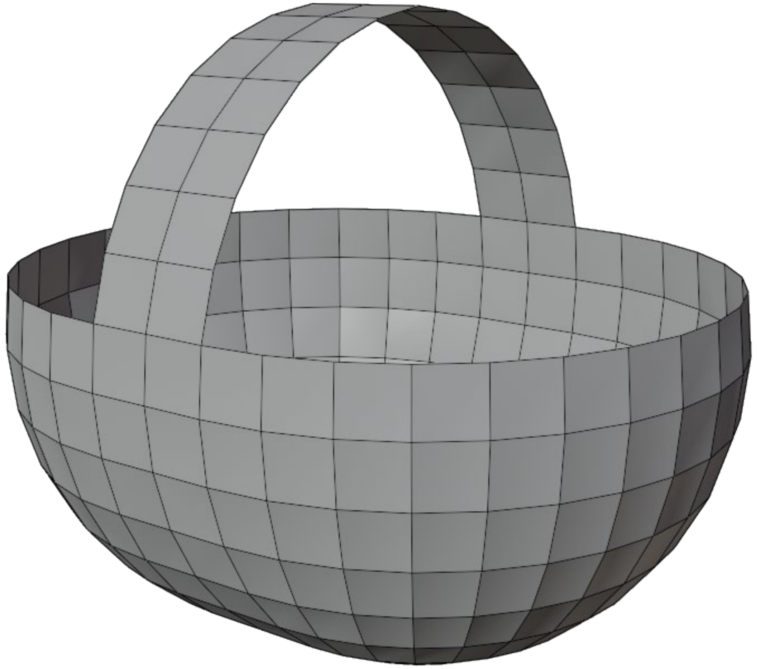
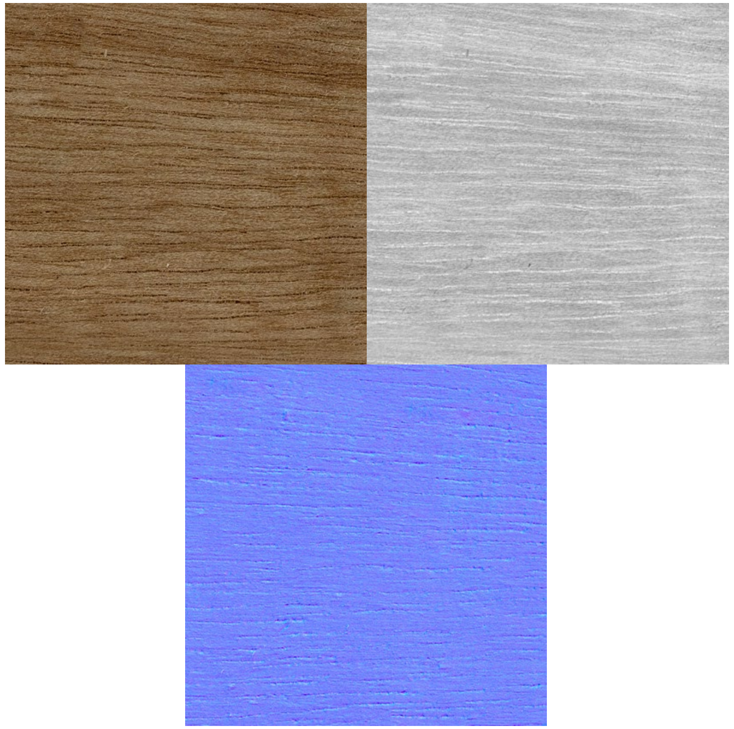


MACRO

3D MESH



MICRO

TEXTURES

MESOSTRUCTURE

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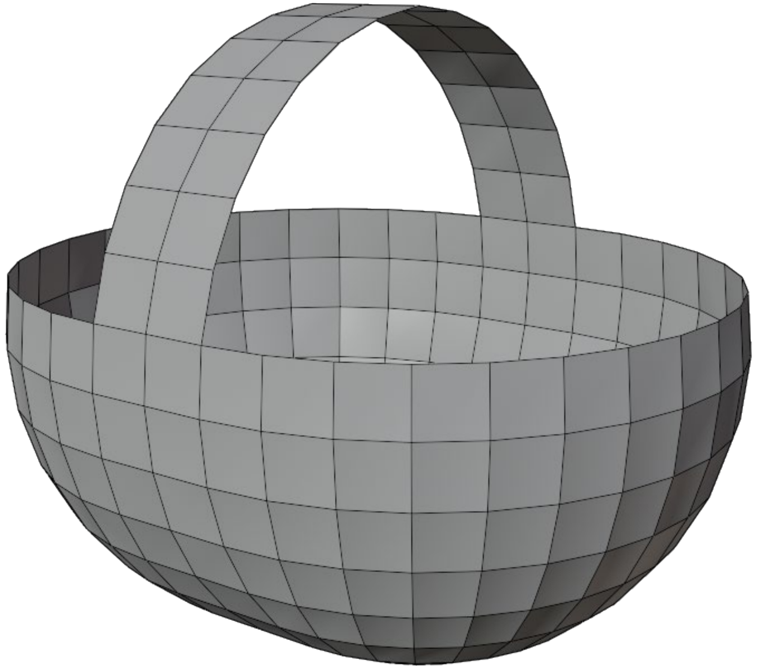
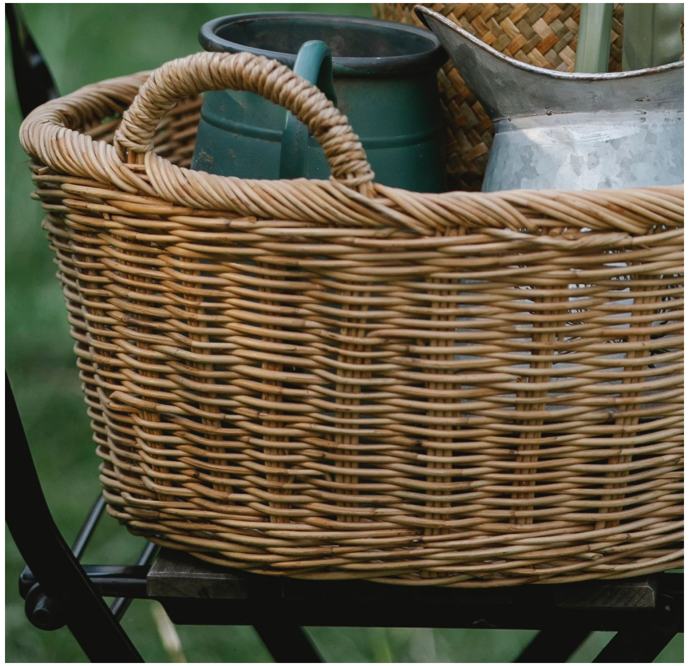


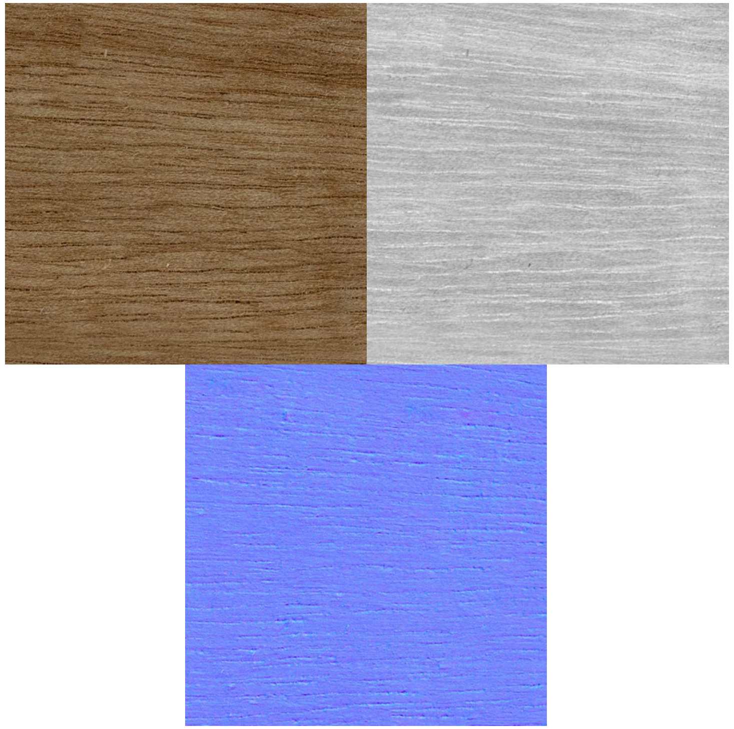
MACRO

3D MESH



MESO

?



MICRO

TEXTURES

MESOSTRUCTURE

Complex topology <

> Self-repetition

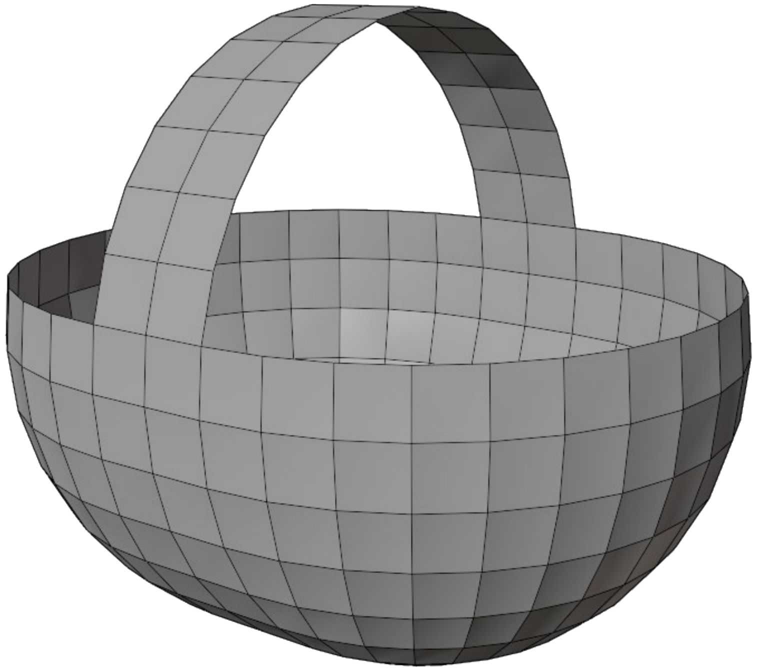
Mapped along a surface

MACRO

MESO

MICRO

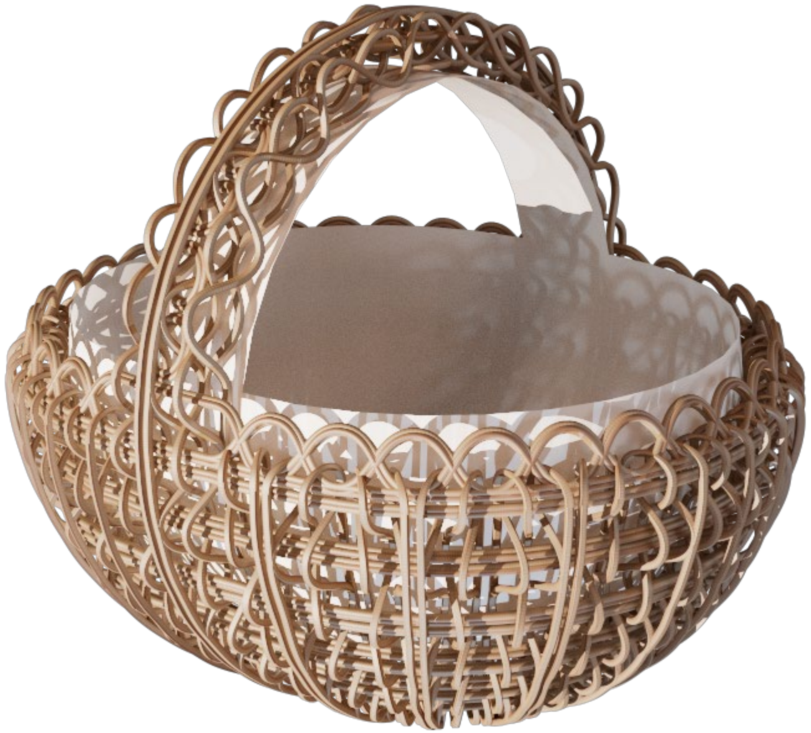
OUR APPROACH



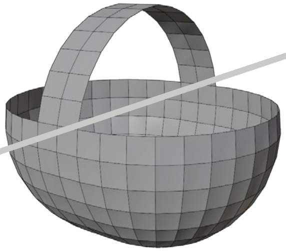
>

MesoGen
WORKFLOW

>



OUR APPROACH



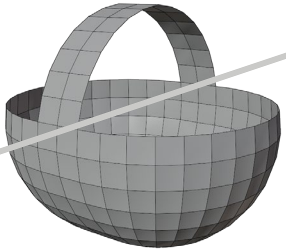
>

MESOGEN
WORKFLOW

>

Tile-based modeling

OUR APPROACH



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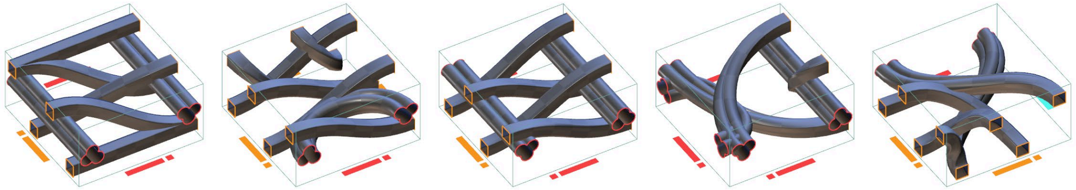
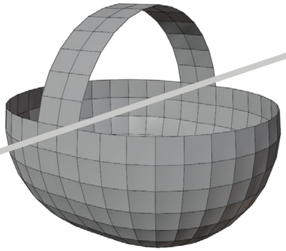


TILE SET
[Wang61]

OUR APPROACH



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MESOGEN WORKFLOW

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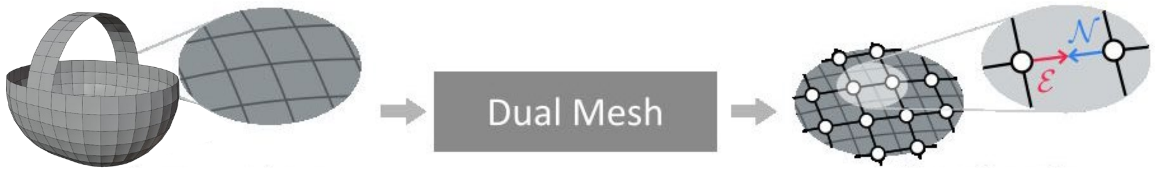
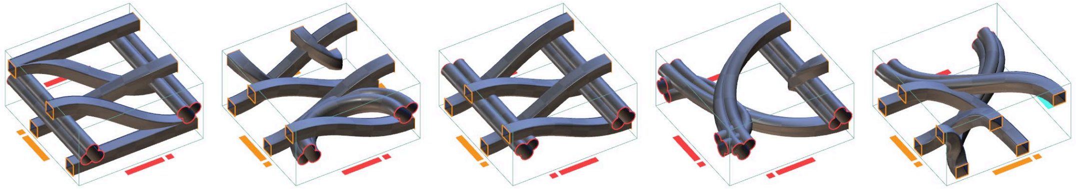


SLOT GRAPH



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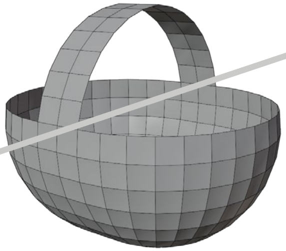

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MesoGen WORKFLOW

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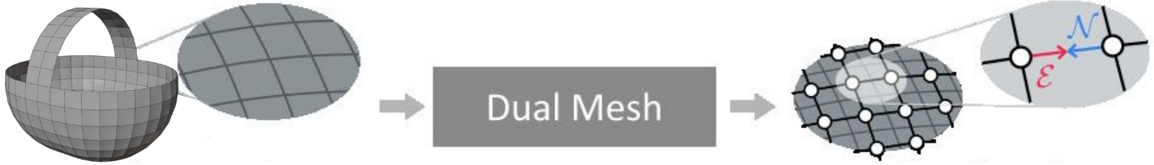

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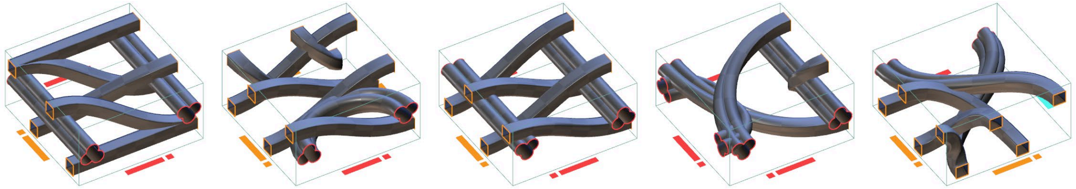

TILE SET
[Wang61]

> TILING ENGINE >

[Merrell07]
[Gumin16]

MESOSTRUCTURE

TILE-BASED CONTENT CREATION

PROS

CONS

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V

We benefit from this…

C

V

… and address that

A B

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TILE SET CREATION

TILE SET CREATION

- **Challenge:** Ensuring **continuity**-by-construction

TILE SET =

A TILE SET CREATION

- **Challenge:** Ensuring **continuity**-by-construction

TILE SET = COMBINATORIAL INFO +

TILE SET CREATION

- **Challenge:** Ensuring **continuity**-by-construction

TILE SET = COMBINATORIAL INFO + GEOMETRIC CONTENT

A TILE SET CREATION

- **Challenge:** Ensuring **continuity**-by-construction

$$\text{TILE SET} = \underbrace{\text{COMBINATORIAL INFO} + \text{GEOMETRIC CONTENT}}_{\text{MUST BE CONSISTENT}}$$

A TILE SET CREATION

- **Challenge:** Ensuring **continuity**-by-construction

COMBINATORIAL INFORMATION

GEOMETRIC CONTENT

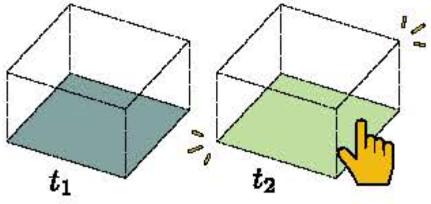
∧

JOINT PROCESS >

A TILE SET CREATION

- **Challenge:** Ensuring **continuity**-by-construction

COMBINATORIAL INFORMATION



Add Tiles T

GEOMETRIC CONTENT

∧

JOINT PROCESS

>

TILE SET CREATION

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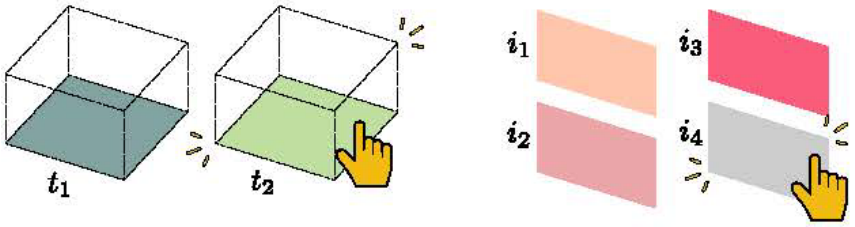
COMBINATORIAL INFORMATION



Add Tiles T

Add Interfaces I

GEOMETRIC CONTENT

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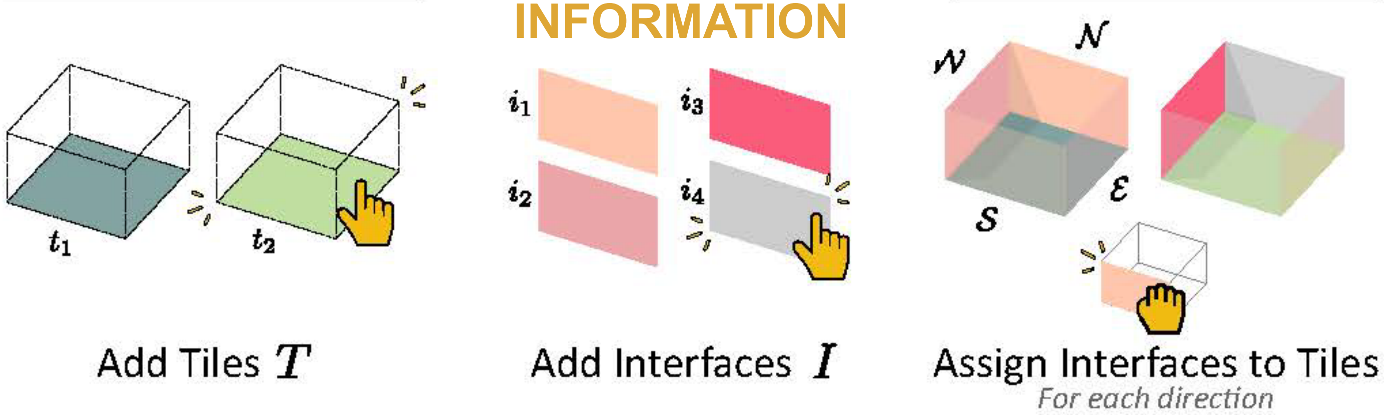
JOINT PROCESS

>

A TILE SET CREATION

- **Challenge:** Ensuring **continuity**-by-construction

COMBINATORIAL INFORMATION



Add Tiles T

Add Interfaces I

Assign Interfaces to Tiles
For each direction

GEOMETRIC CONTENT

∧

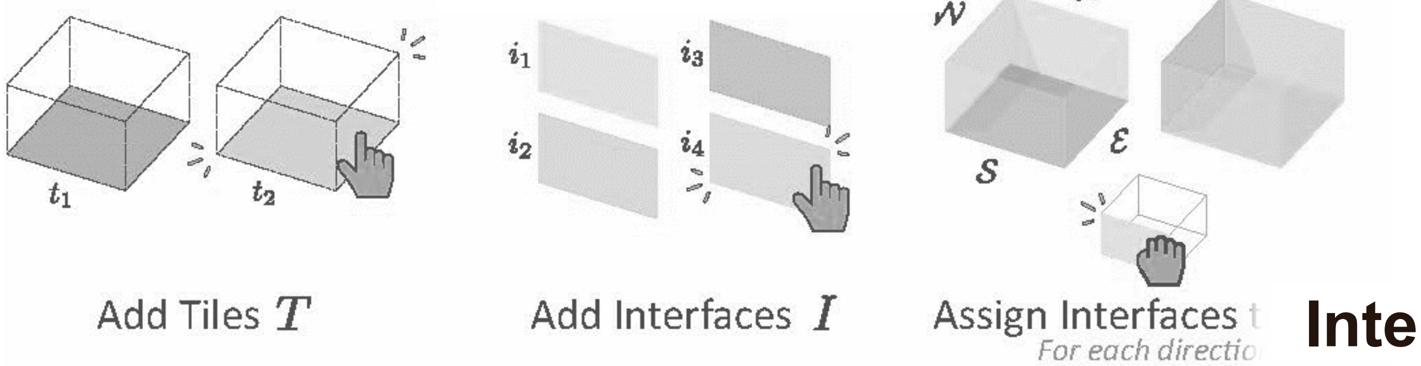
JOINT PROCESS

>

A TILE SET CREATION

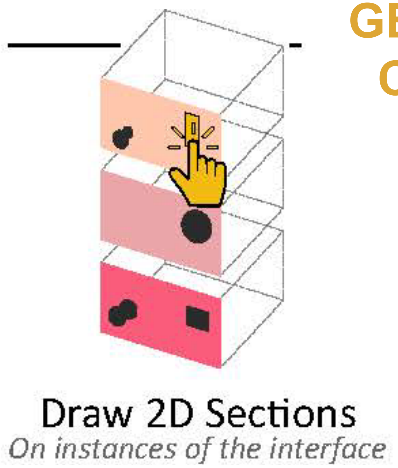
- **Challenge:** Ensuring **continuity**-by-construction

COMBINATORIAL INFORMATION



Interface-first! [Bian18]

GEOMETRIC CONTENT



∧

JOINT PROCESS

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TILE SET CREATION

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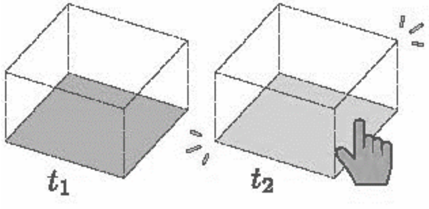
COMBINATORIAL INFORMATION



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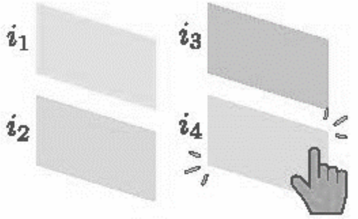

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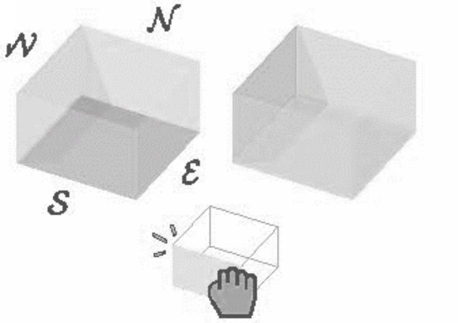

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JOINT PROCESS

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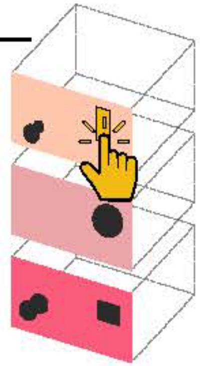
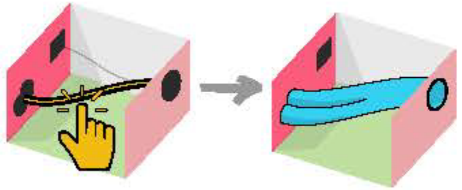
GEOMETRIC CONTENT



Draw 2D Sections

On instances of the interface



Select 3D sweep surfaces

Define tiles' content

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SOLVING TIME

TILE SUGGESTION

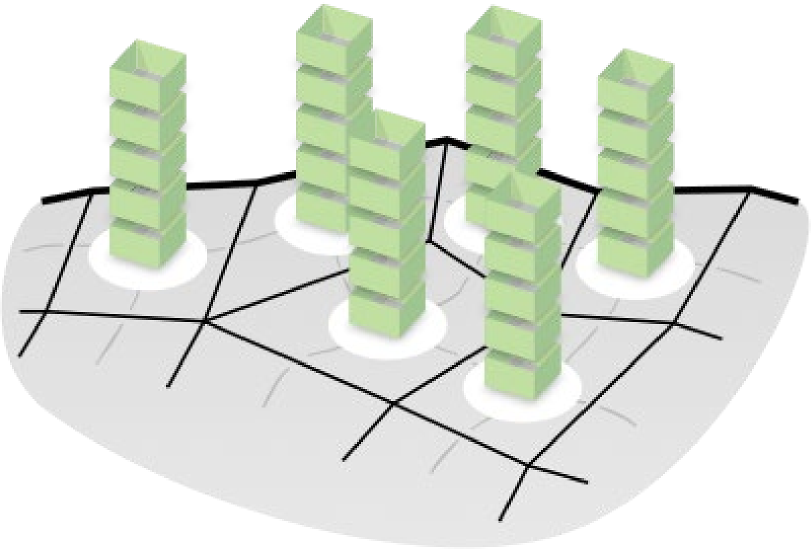
B TILE SUGGESTION

- **Challenge:** Ensuring **interactive** tiling engine

(while solving is NP-hard)

B TILE SUGGESTION

- **Algorithm:** Tiling engine [Merrell07] [Gumin16]



B TILE SUGGESTION

Sets of tile

🟩 Left unchanged

🟥 Modified during this step

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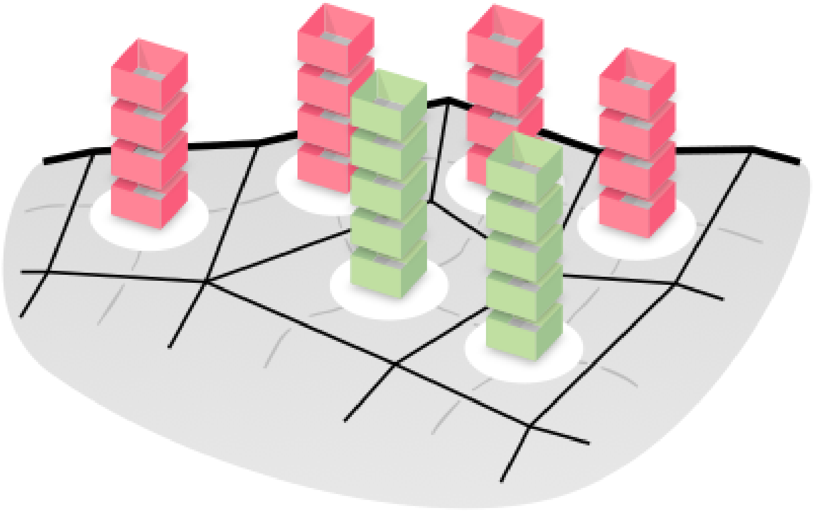

Initialize

Apply border constraints

B TILE SUGGESTION

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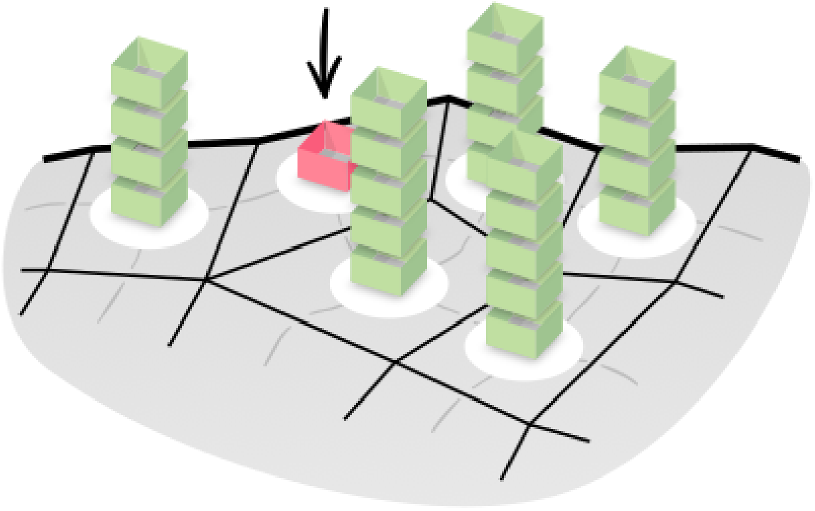

Observe

Random reduction

B TILE SUGGESTION

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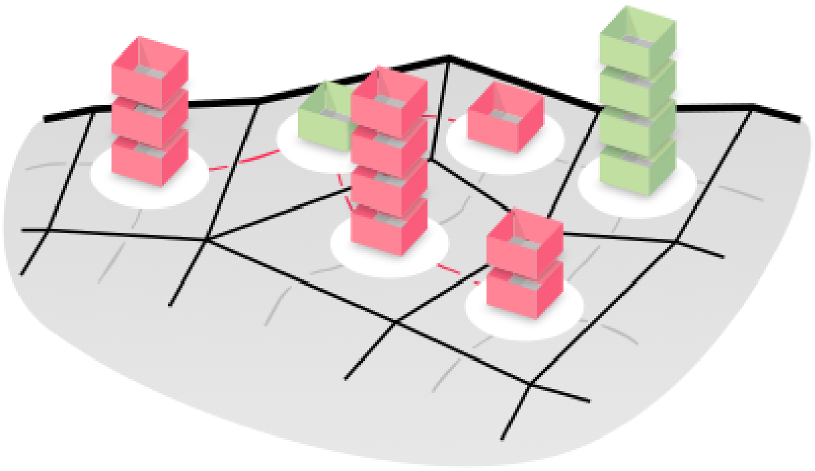

Collapse

Constraint propagation

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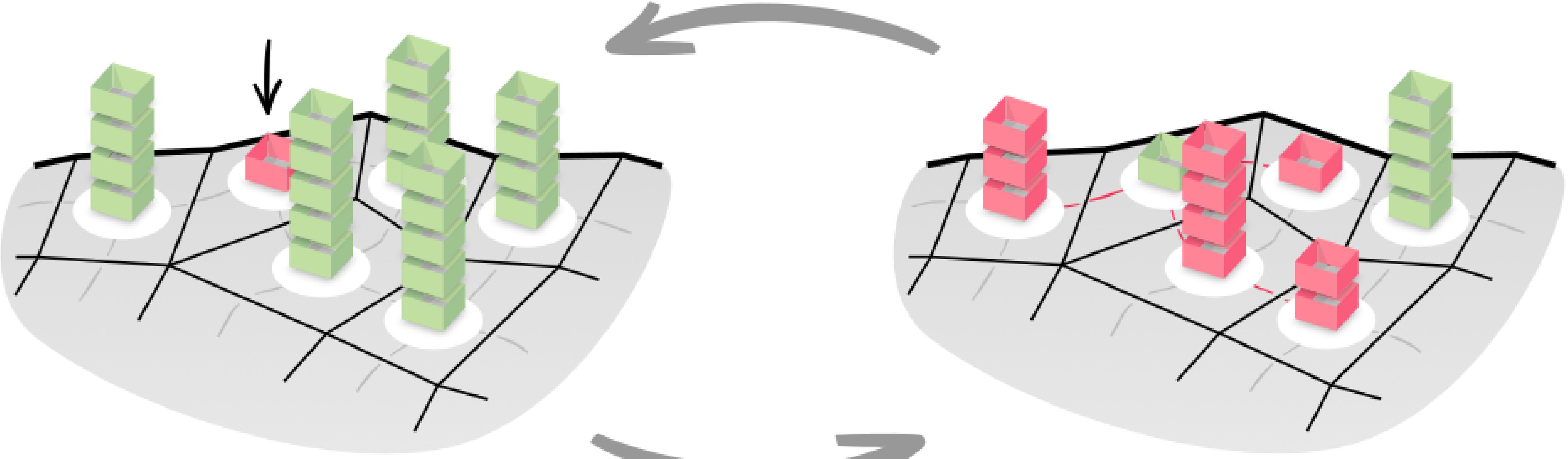

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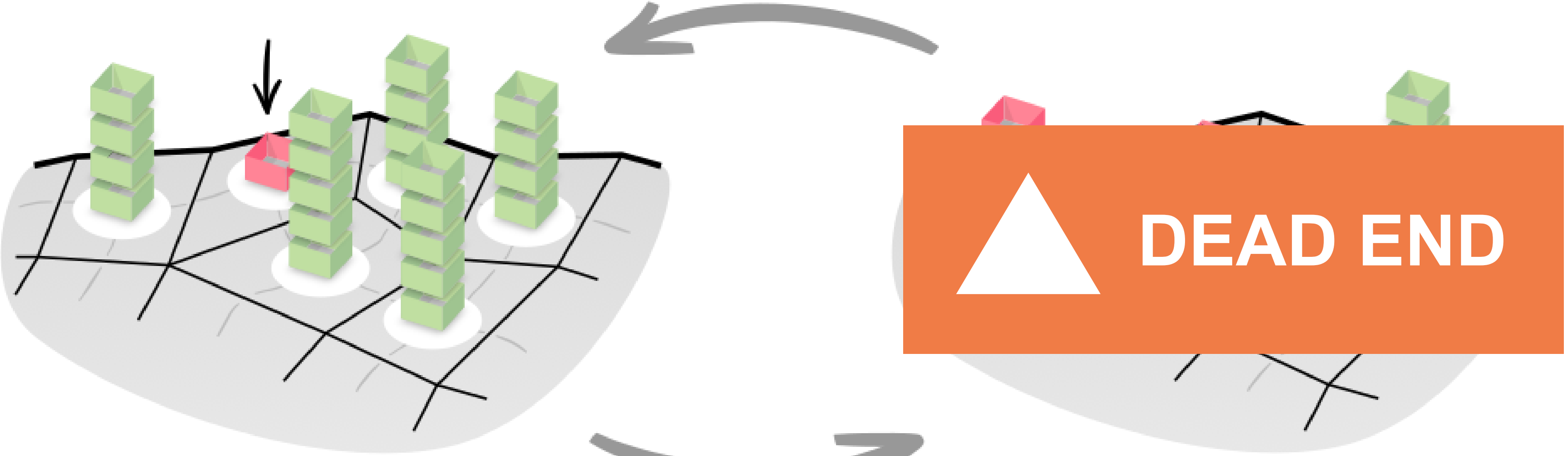

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Random reduction

Collapse
Constraint propagation

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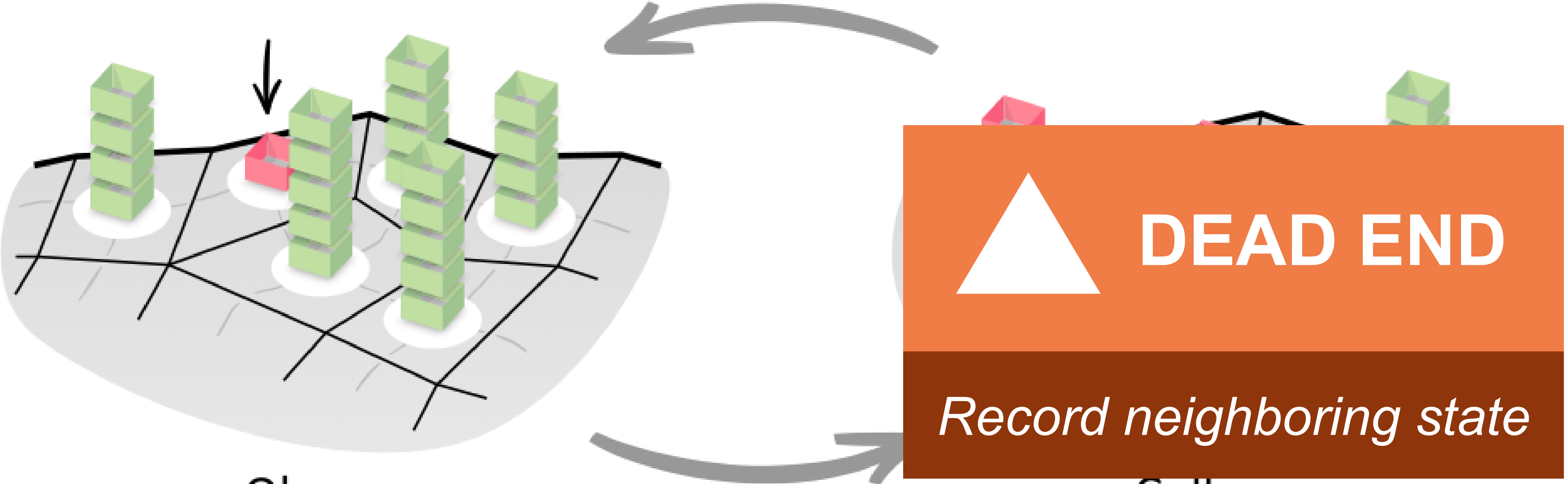

DEAD END

Record neighboring state

Observe

Random reduction

Collapse

Constraint propagation

TILE SUGGESTION

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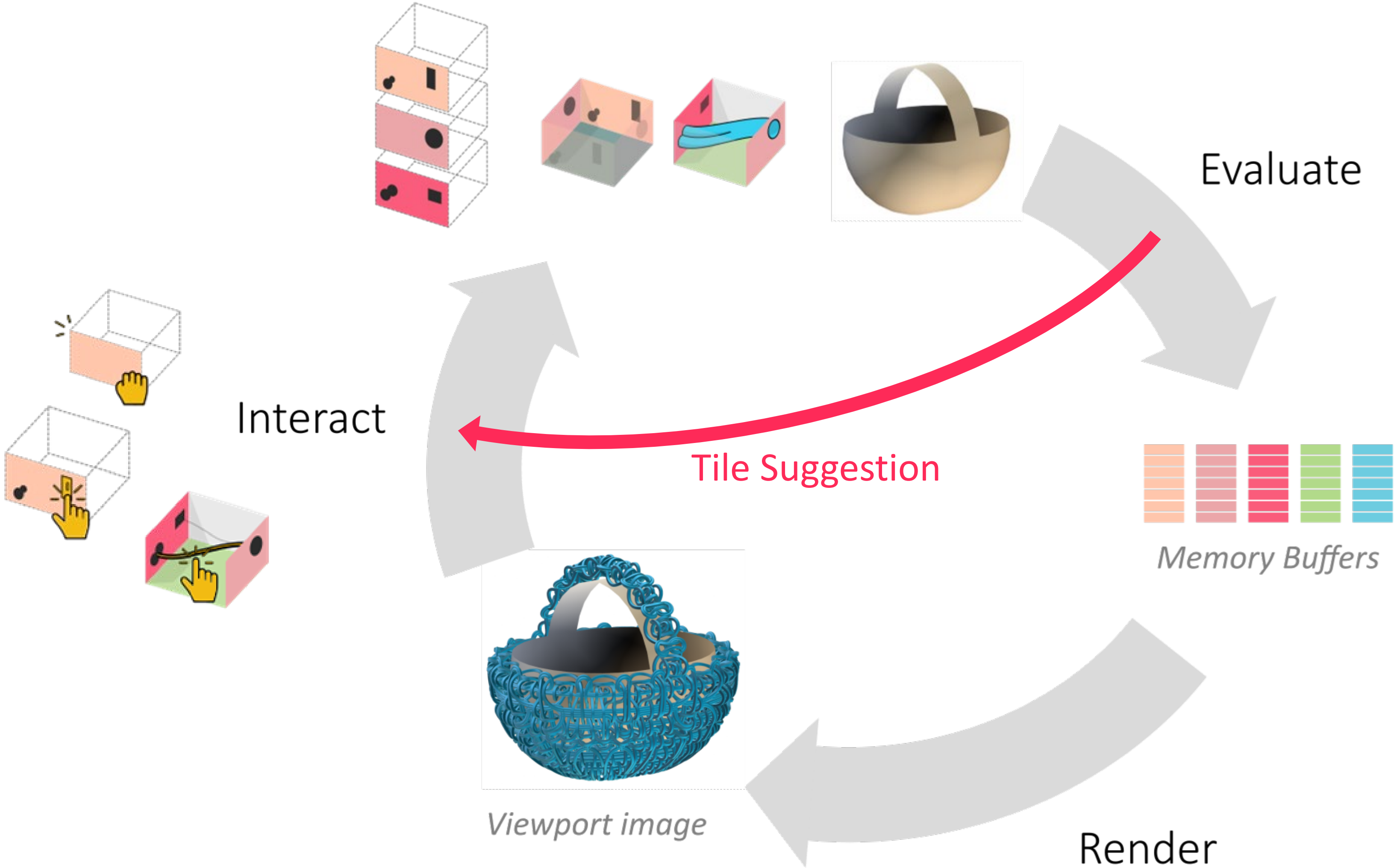
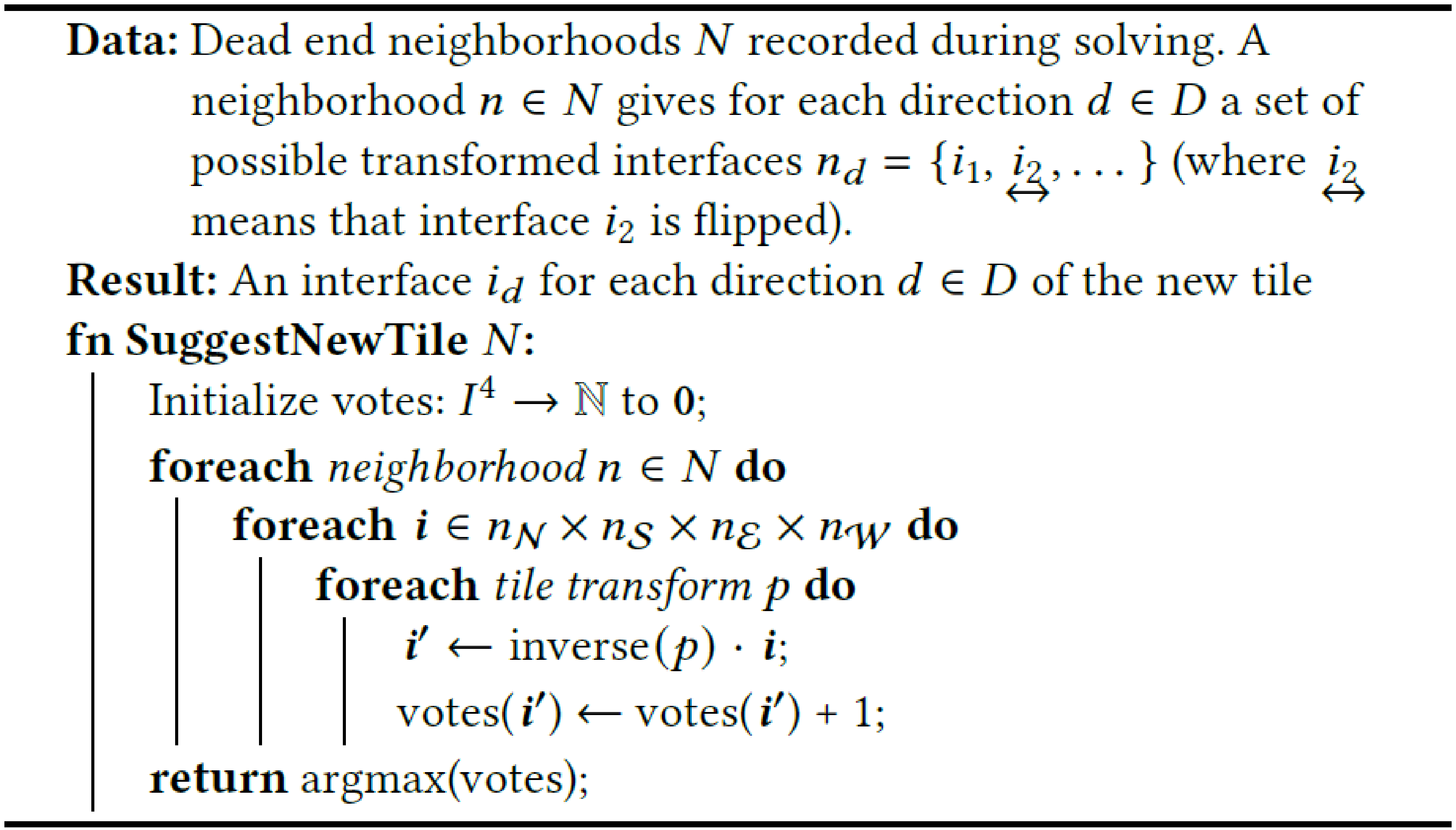


B TILE SUGGESTION

- **Algorithm:** Tile suggestion = Voting



```
Data: Dead end neighborhoods $N$ recorded during solving. A
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      possible transformed interfaces $n_d = \{i_1, \underset{\leftrightarrow}{i_2}, \ldots\}$ (where $\underset{\leftrightarrow}{i_2}$
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Result: An interface $i_d$ for each direction $d \in D$ of the new tile
fn SuggestNewTile $N$:
    Initialize votes: $I^4 \longrightarrow \mathbb{N}$ to $\mathbf{0}$;
    foreach neighborhood $n \in N$ do
        foreach $\boldsymbol{i} \in n_N \times n_S \times n_E \times n_W$ do
            foreach tile transform $p$ do
                $\boldsymbol{i}' \leftarrow \mathrm{inverse}(p) \cdot \boldsymbol{i}$;
                $\mathrm{votes}(\boldsymbol{i}') \leftarrow \mathrm{votes}(\boldsymbol{i}') + 1$;
    return argmax(votes);
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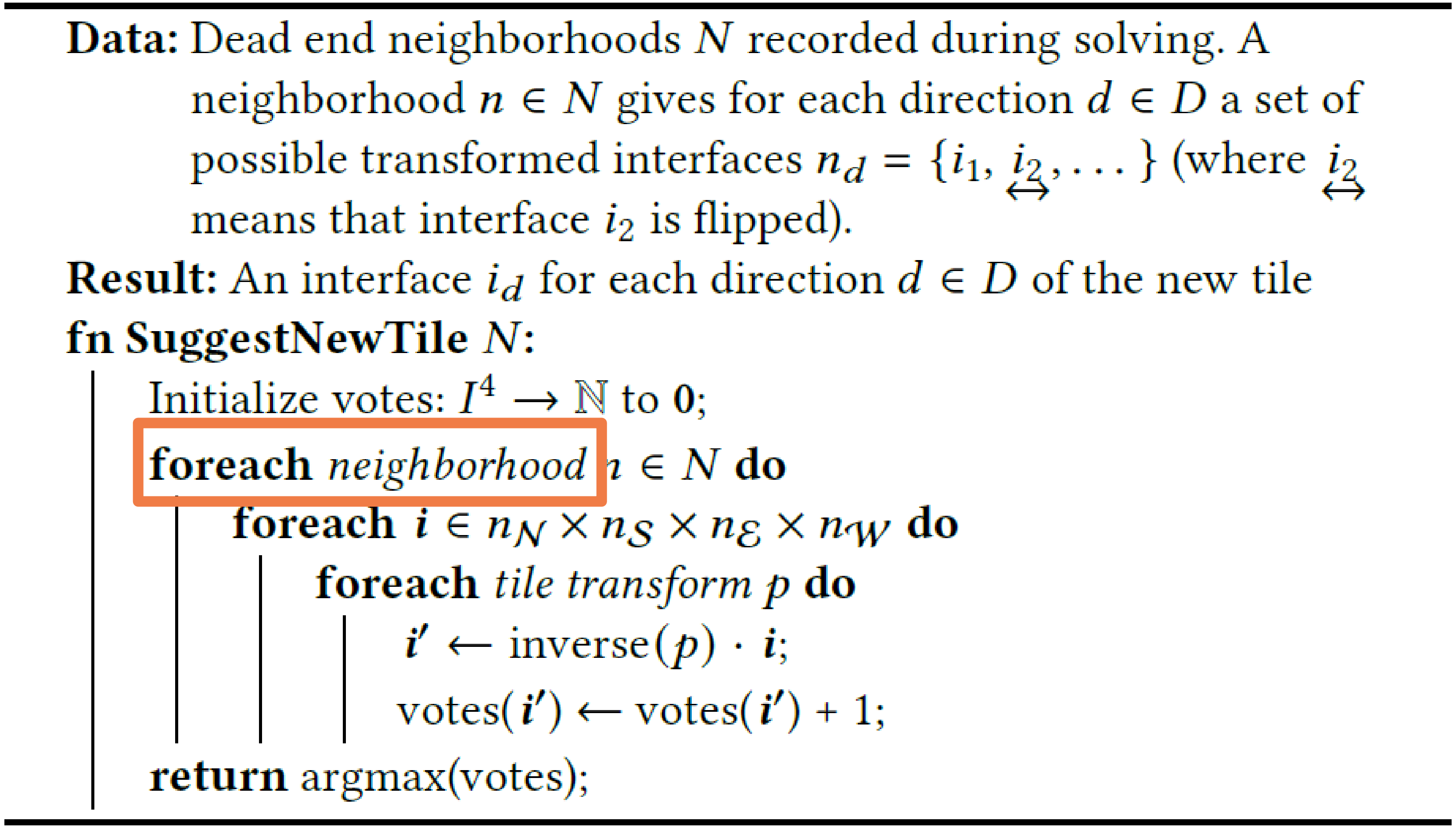

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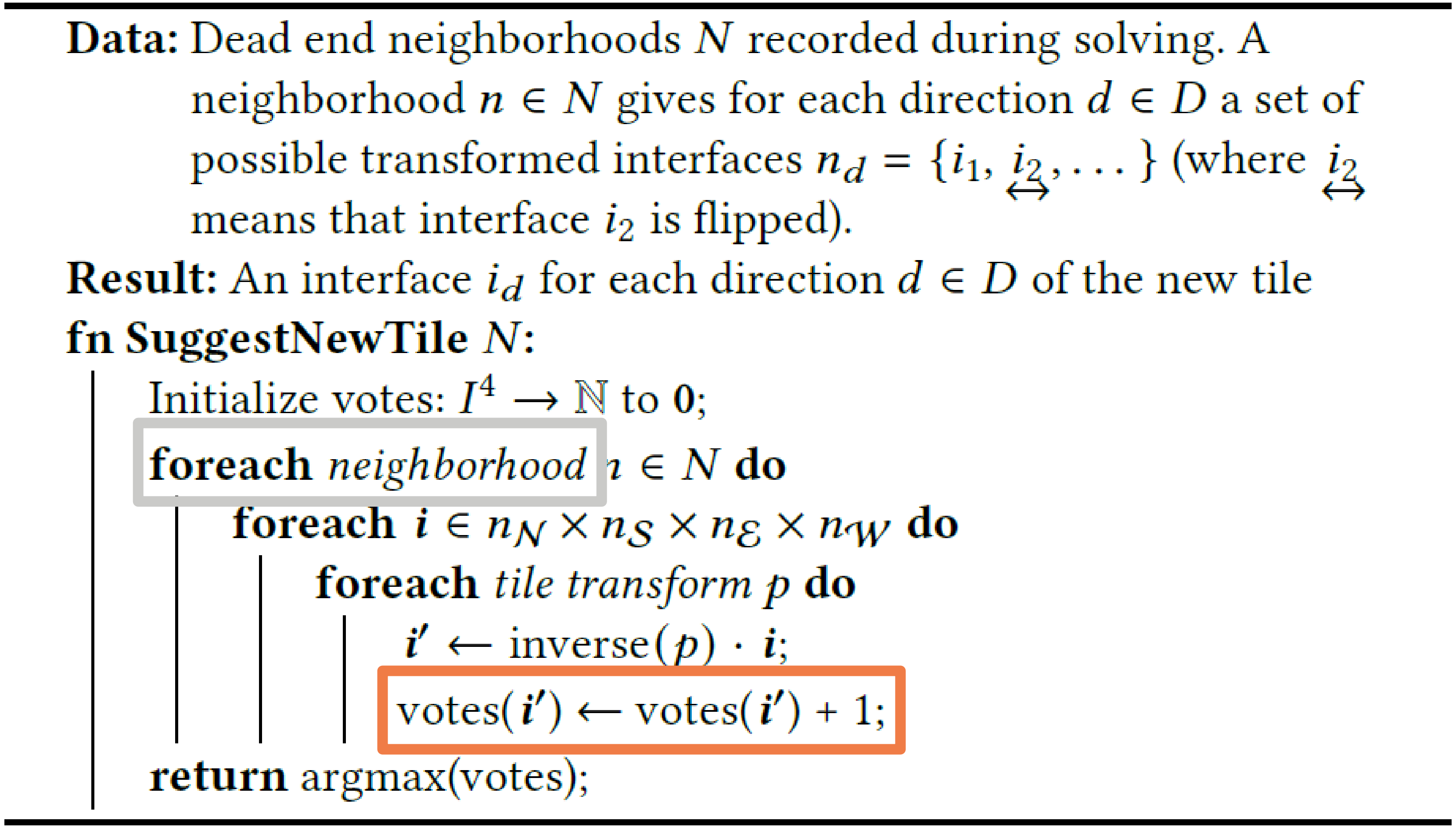

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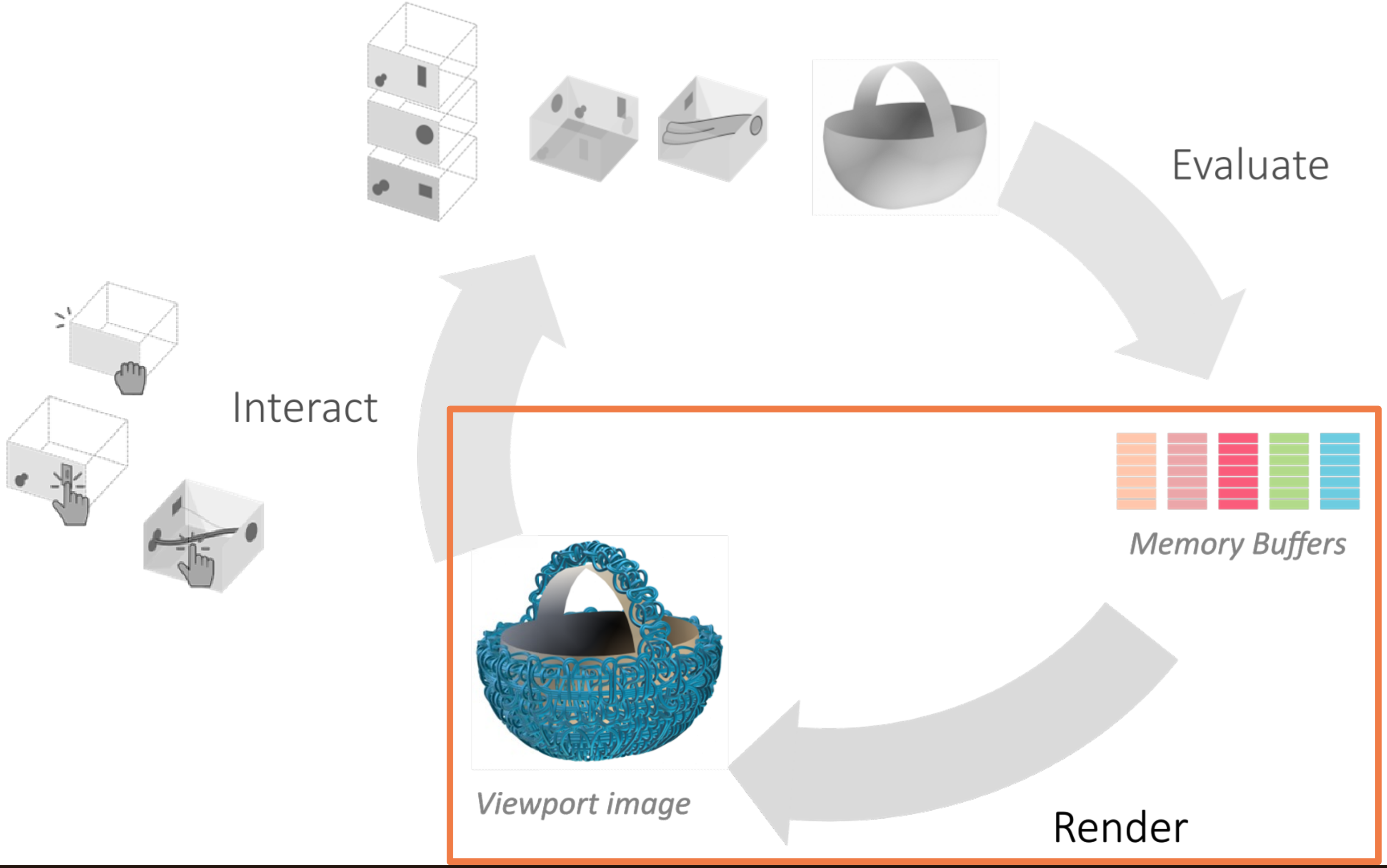
COMPACT MODEL

VISUAL FEEDBACK

C VISUAL FEEDBACK

- **Challenge:** Provide **real-time** visual feedback



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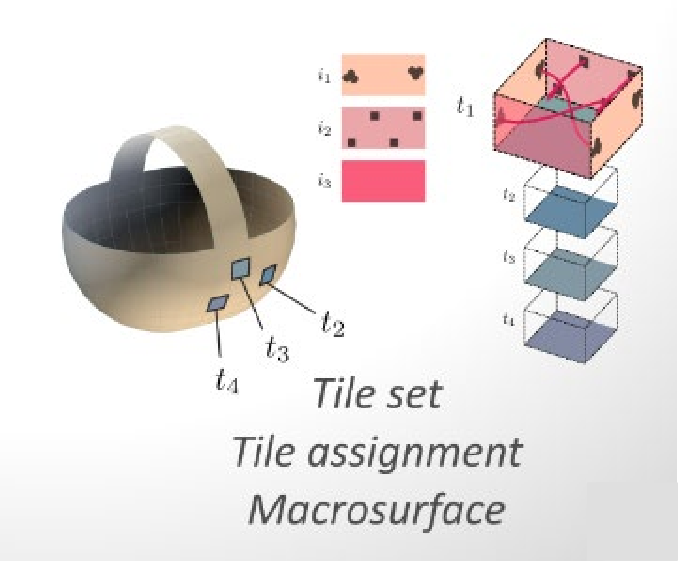

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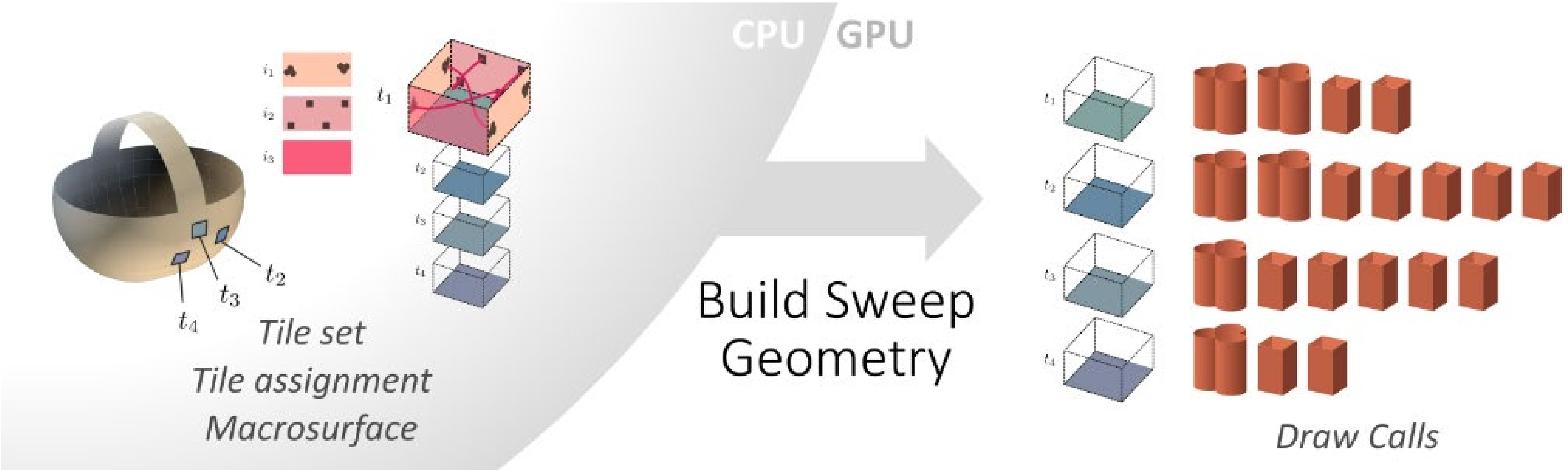

Tile set

Tile assignment

Macrosurface

Build Sweep Geometry

Draw Calls

C VISUAL FEEDBACK

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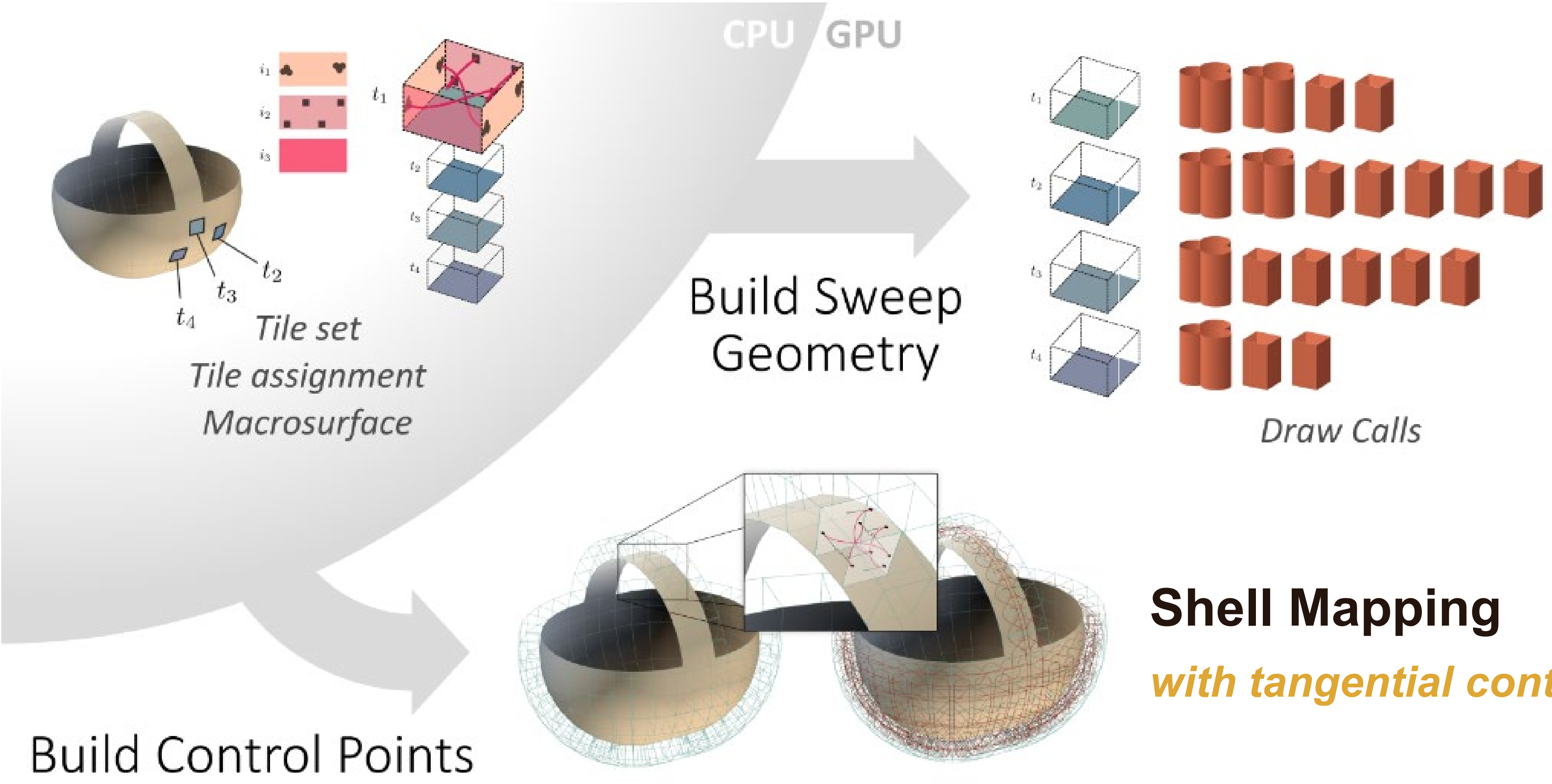

Shell Mapping

with tangential continuity

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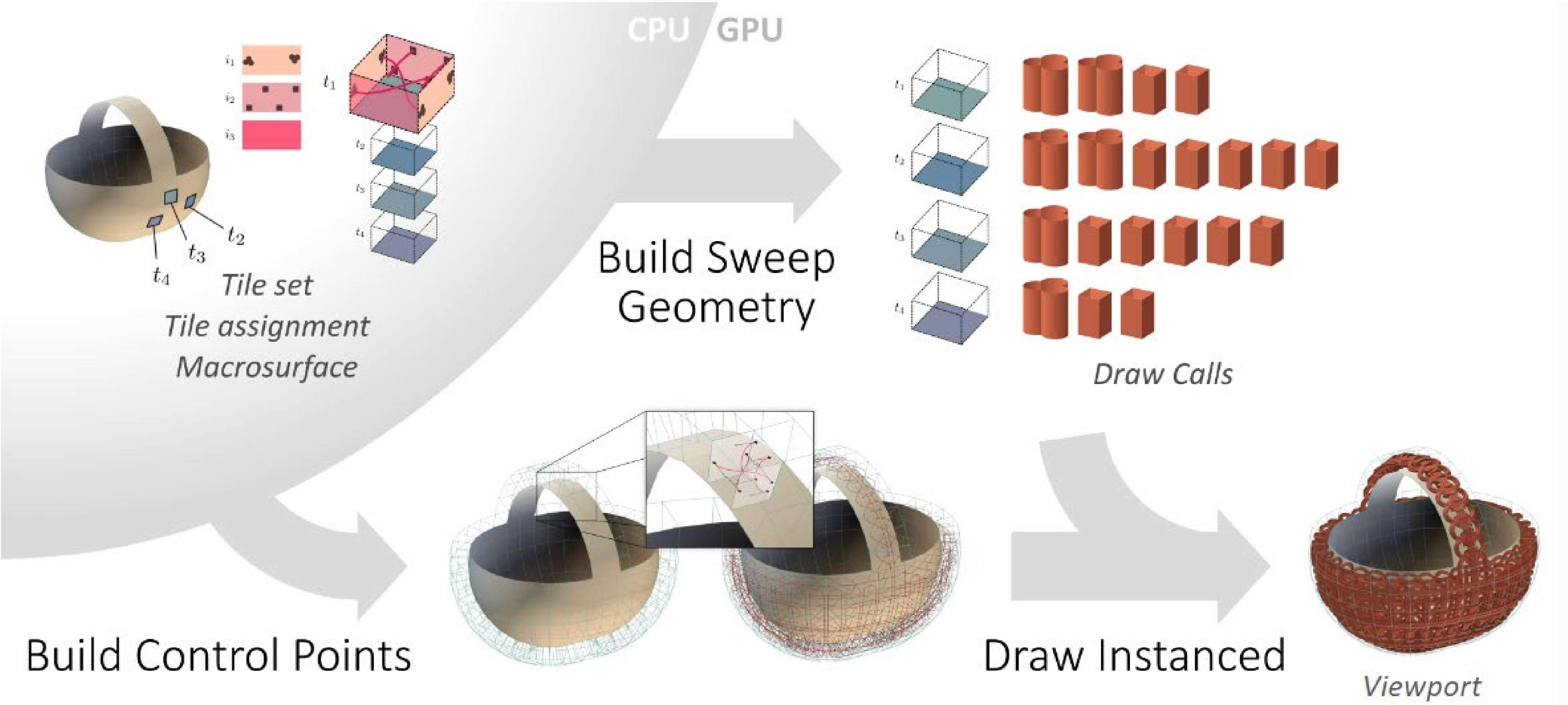

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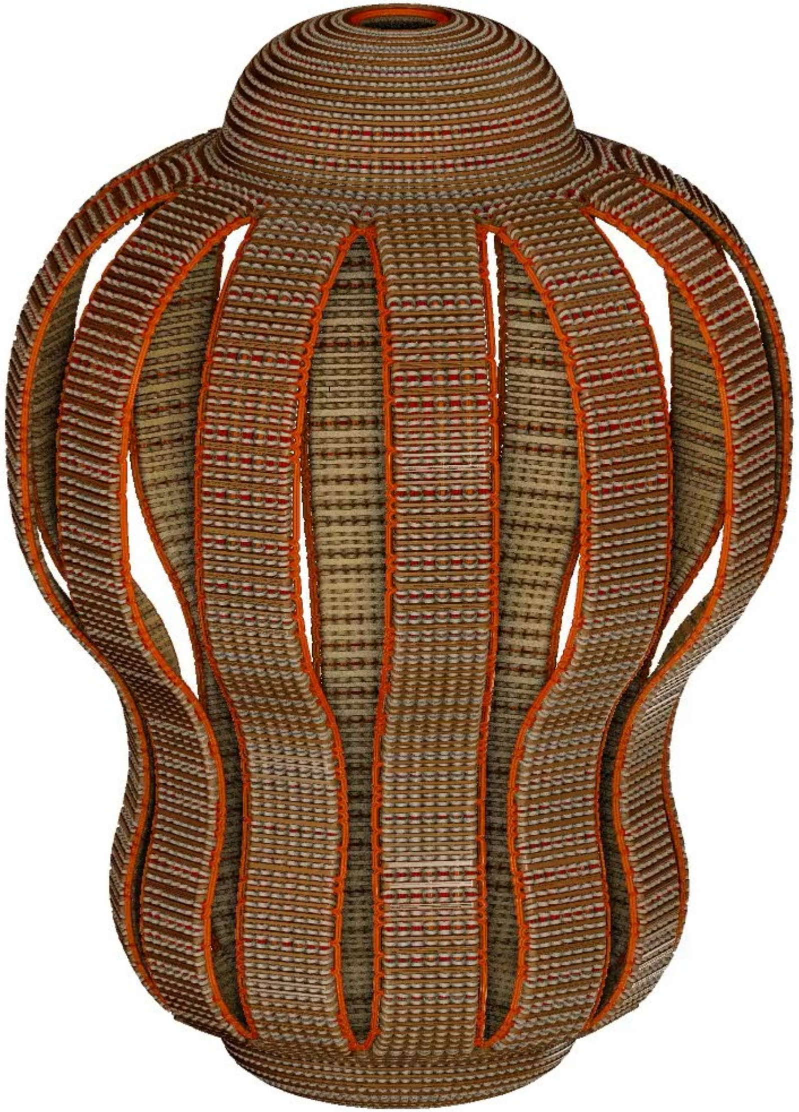
RESULTS

RESULTS



105M triangles

Memory footprint

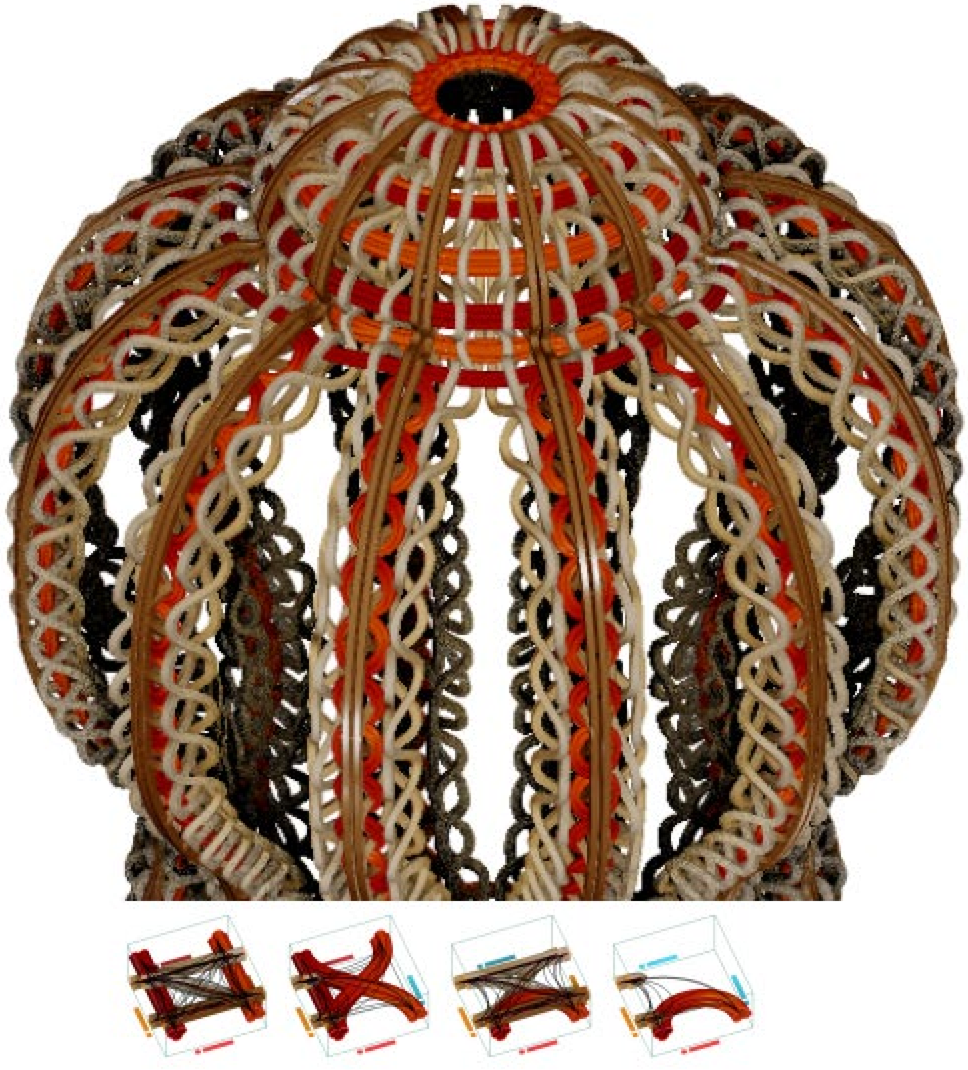
ours: **9.71 MB**

mesh: **2 690 MB**

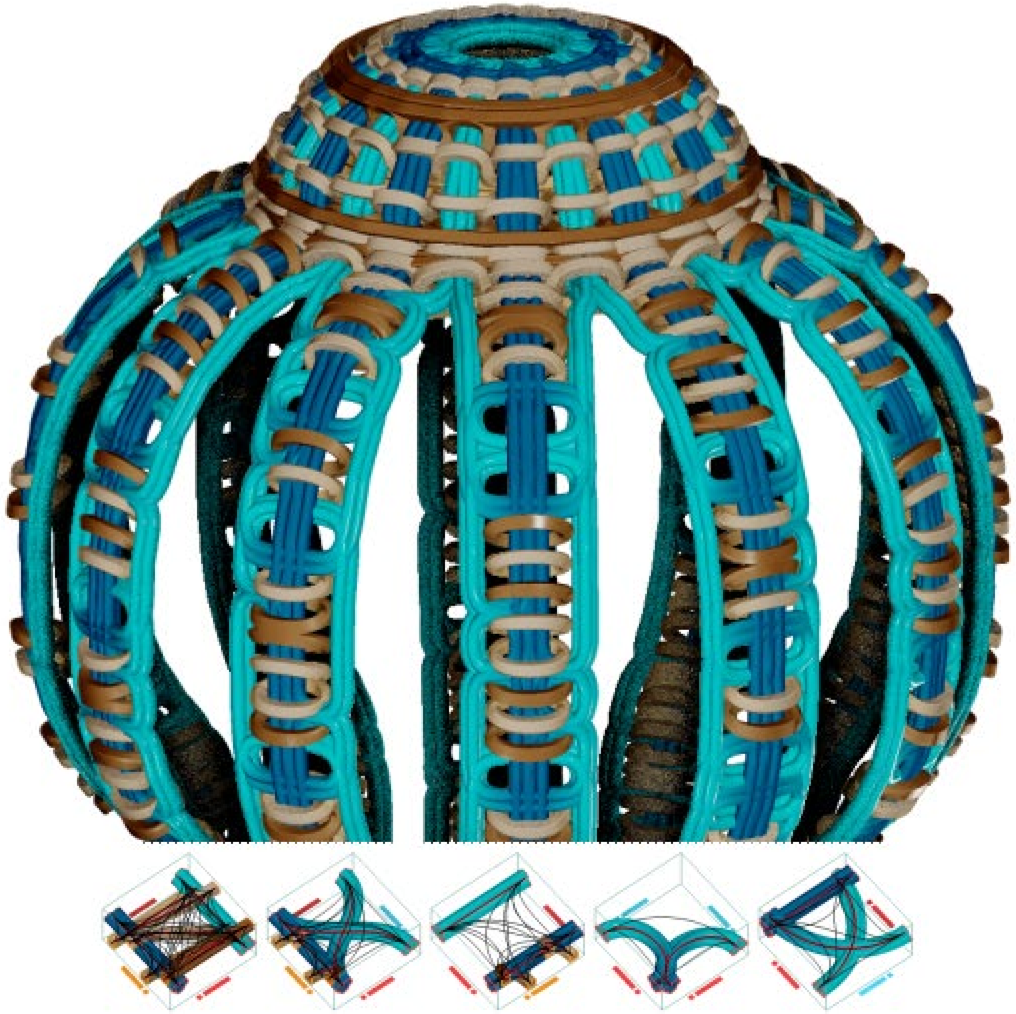
Render time

24 ms per frame

RESULTS

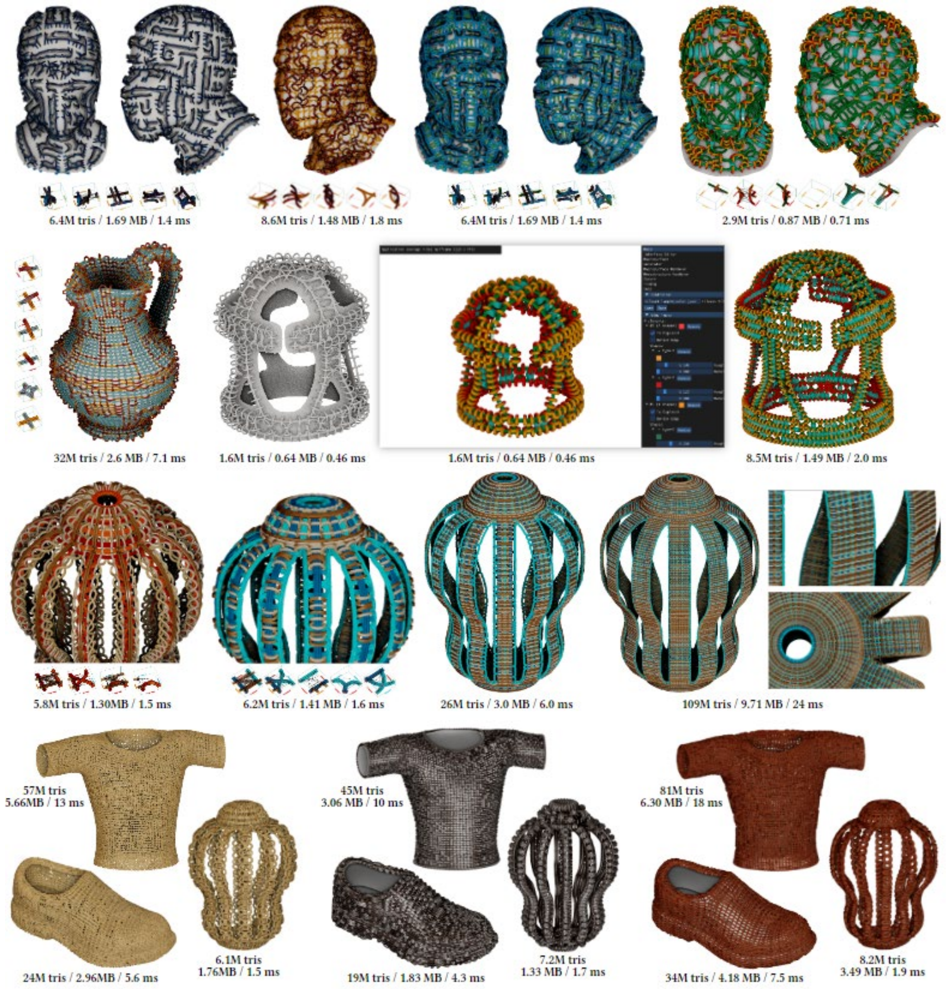


5.8M tris / 1.30MB / 1.5 ms



6.2M tris / 1.41 MB / 1.6 ms

RESULTS


6.4M tris / 1.69 MB / 1.4 ms
8.6M tris / 1.48 MB / 1.8 ms
6.4M tris / 1.69 MB / 1.4 ms
2.9M tris / 0.87 MB / 0.71 ms
32M tris / 2.6 MB / 7.1 ms
1.6M tris / 0.64 MB / 0.46 ms
1.6M tris / 0.64 MB / 0.46 ms
8.5M tris / 1.49 MB / 2.0 ms
5.8M tris / 1.30MB / 1.5 ms
6.2M tris / 1.41 MB / 1.6 ms
26M tris / 3.0 MB / 6.0 ms
109M tris / 9.71 MB / 24 ms
57M tris
5.66MB / 13 ms
45M tris
3.06 MB / 10 ms
81M tris
6.30 MB / 18 ms
24M tris / 2.96MB / 5.6 ms
6.1M tris
1.76MB / 1.5 ms
19M tris / 1.83 MB / 4.3 ms
7.2M tris
1.33 MB / 1.7 ms
34M tris / 4.18 MB / 7.5 ms
8.2M tris
3.49 MB / 1.9 ms

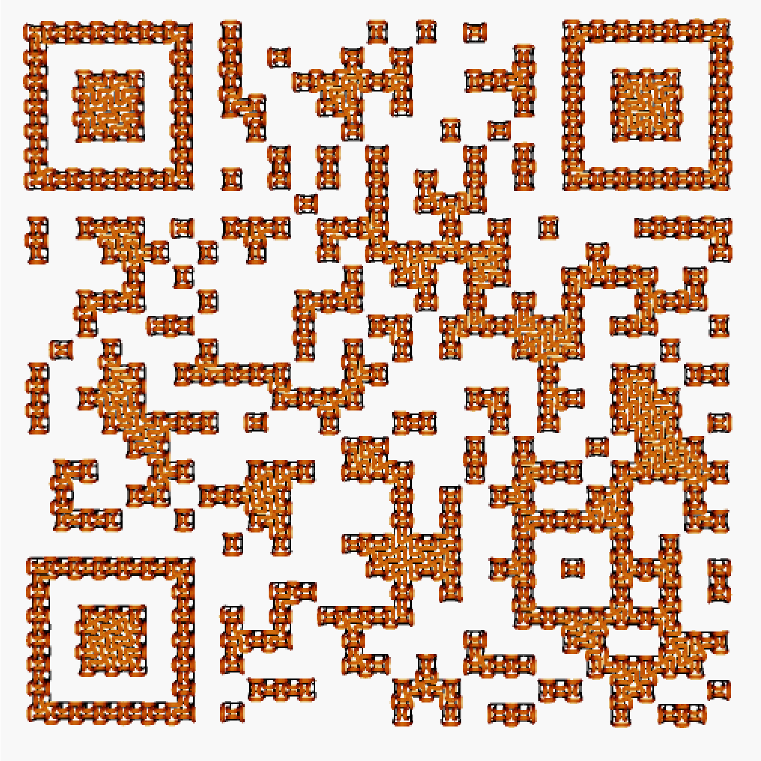
More results available **in the paper**!

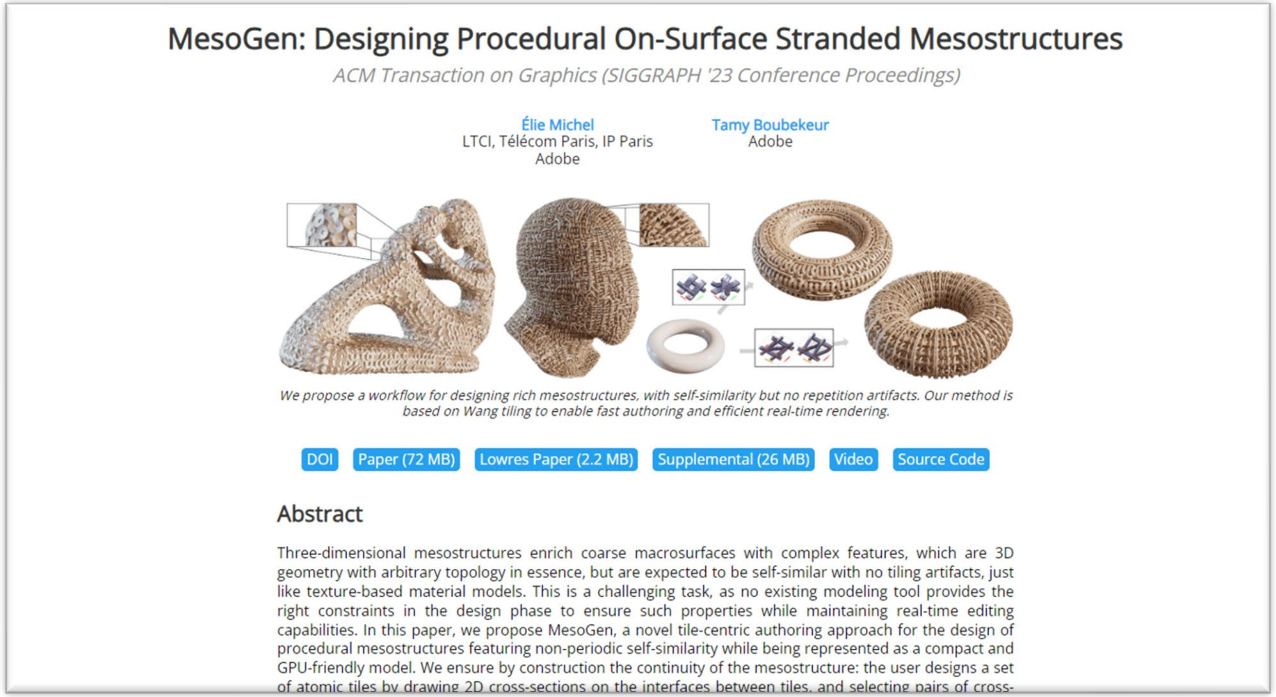
CONCLUSION

We propose an interactive method to:

- Design **complex mesostructures** from a simple **coarse quad mesh**.
- Ensure the **continuity** of the mesostructure **by construction**.
- **Compactly represent** mesostructures in a **GPU-friendly** way.

MORE INFO





MesoGen: Designing Procedural On-Surface Stranded Mesostructures

ACM Transaction on Graphics (SIGGRAPH '23 Conference Proceedings)

Élie Michel
LTCI, Télécom Paris, IP Paris
Adobe

Tamy Boubekeur
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We propose a workflow for designing rich mesostructures, with self-similarity but no repetition artifacts. Our method is based on Wang tiling to enable fast authoring and efficient real-time rendering.

Abstract

Three-dimensional mesostructures enrich coarse macrosurfaces with complex features, which are 3D geometry with arbitrary topology in essence, but are expected to be self-similar with no tiling artifacts, just like texture-based material models. This is a challenging task, as no existing modeling tool provides the right constraints in the design phase to ensure such properties while maintaining real-time editing capabilities. In this paper, we propose MesoGen, a novel tile-centric authoring approach for the design of procedural mesostructures featuring non-periodic self-similarity while being represented as a compact and GPU-friendly model. We ensure by construction the continuity of the mesostructure: the user designs a set of atomic tiles by drawing 2D cross-sections on the interfaces between tiles, and selecting pairs of cross-

https://eliemichel.github.io/MesoGen

Test our Open Source prototype!

End of slideshow