Iterative carving for self-supporting 3D-printing cavities

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MFX Team, Inria

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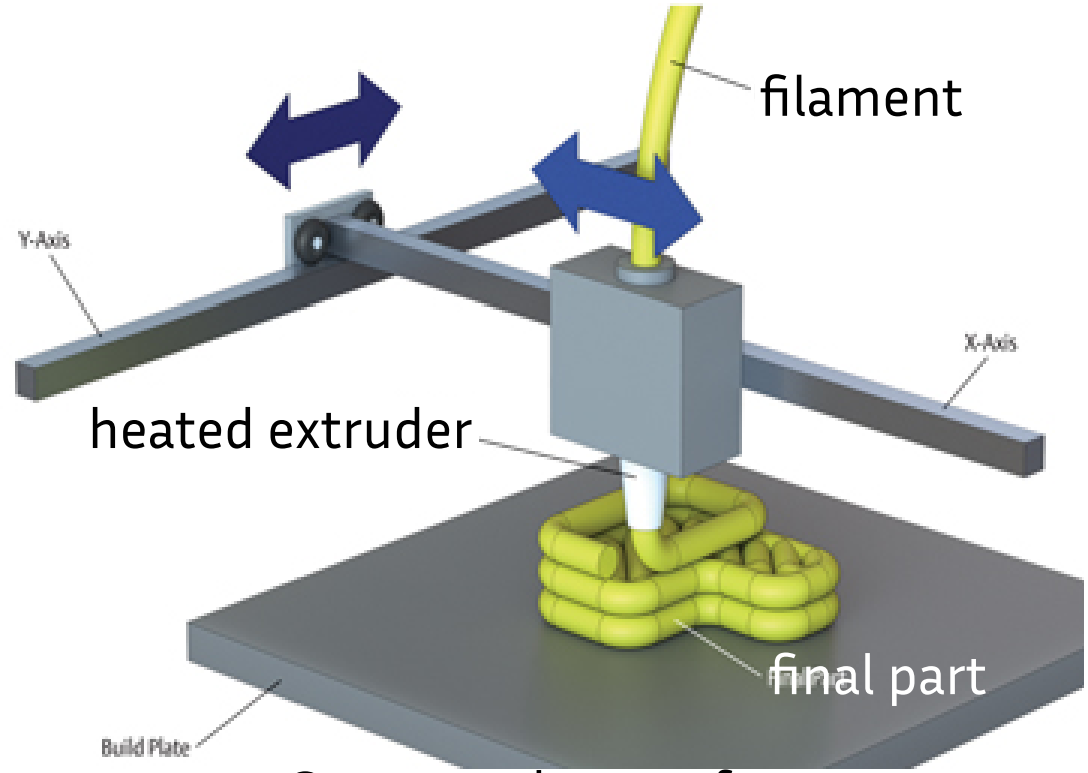
Eurographics 2018 – short papers track

The problem

Context:

- Additive manufacturing
- Fused Filament Fabrication



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Problem: scaling.

Print in 1h $\Rightarrow$ Scale object 10$\times$ $\Rightarrow$ Print in 41 days.

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Infill helps : interior filled at, *e.g.*, 10 %. Still cubic growth.

The problem

Context:

- Additive manufacturing
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Problem: sc
Print in 1h

Goal: model as-large-as-possible, self-supported cavities inside a shape.

Infill helps : interior filled at, *e.g.*, 10 %. Still cubic growth.

Related Work

[Lee J. and Lee K. *Block-based inner support structure...* Int. J. Adv. Manuf. Technology, 2017]

image taken from [Lee and Lee 2017]

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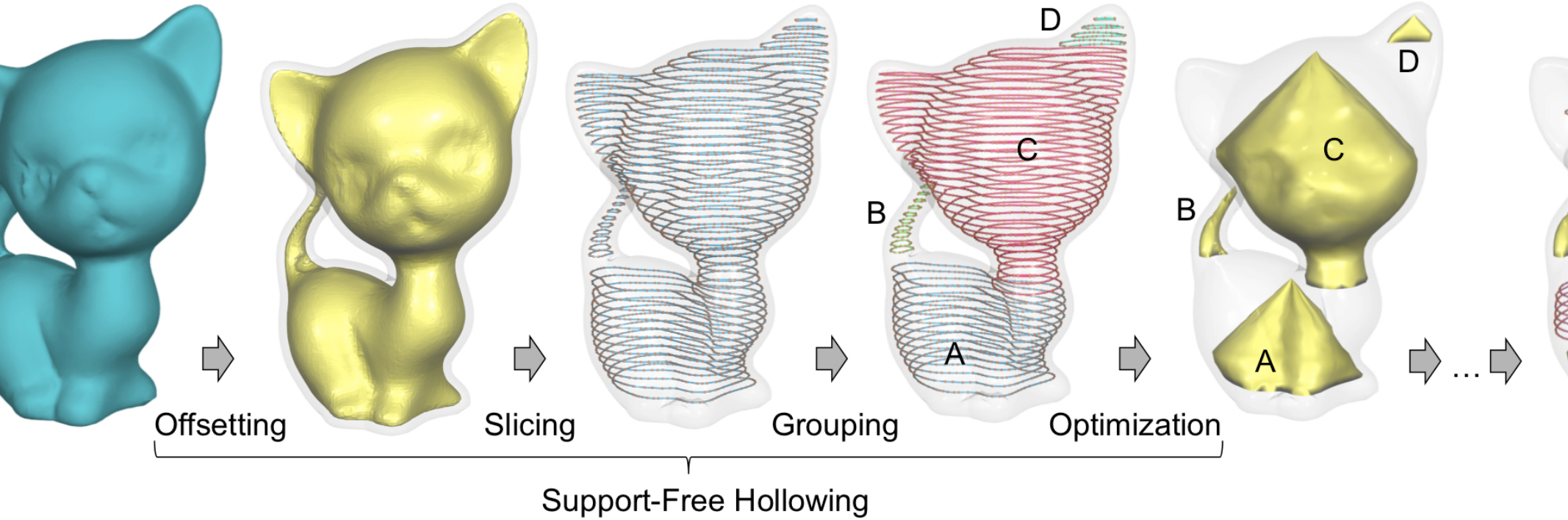

image from [Wang *et al.*]

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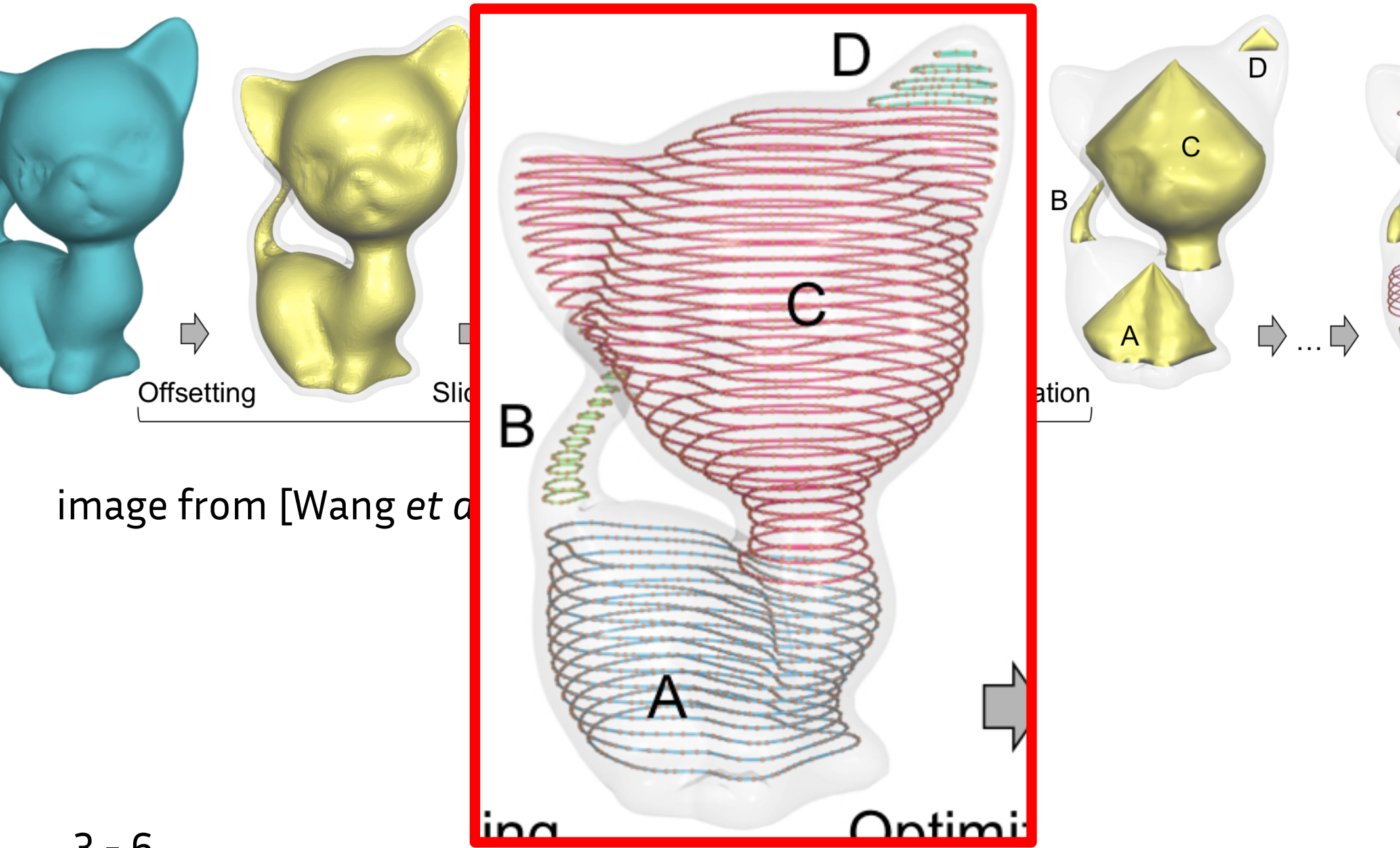

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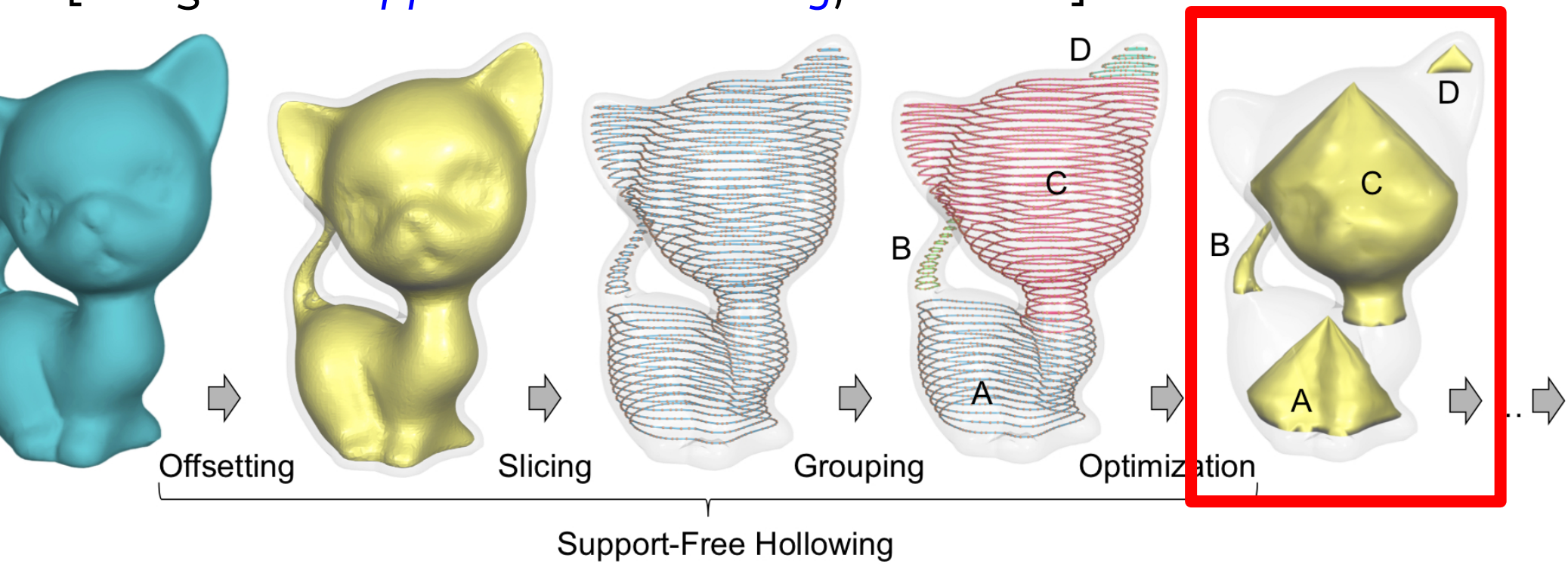

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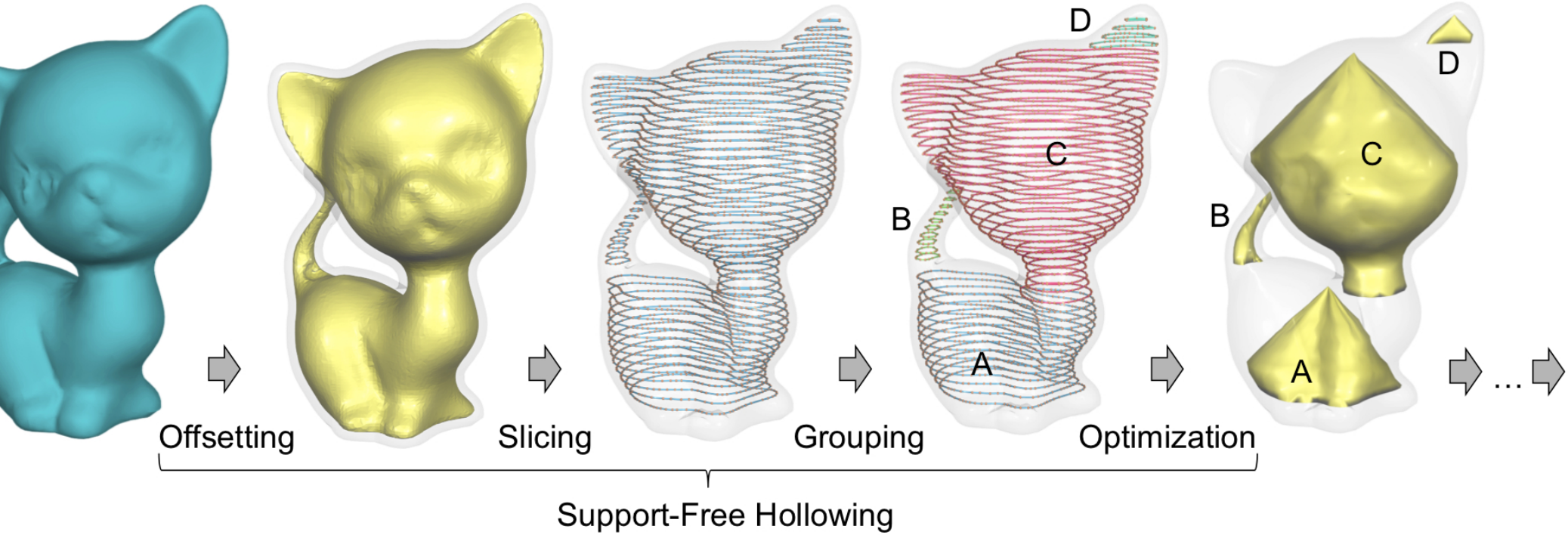
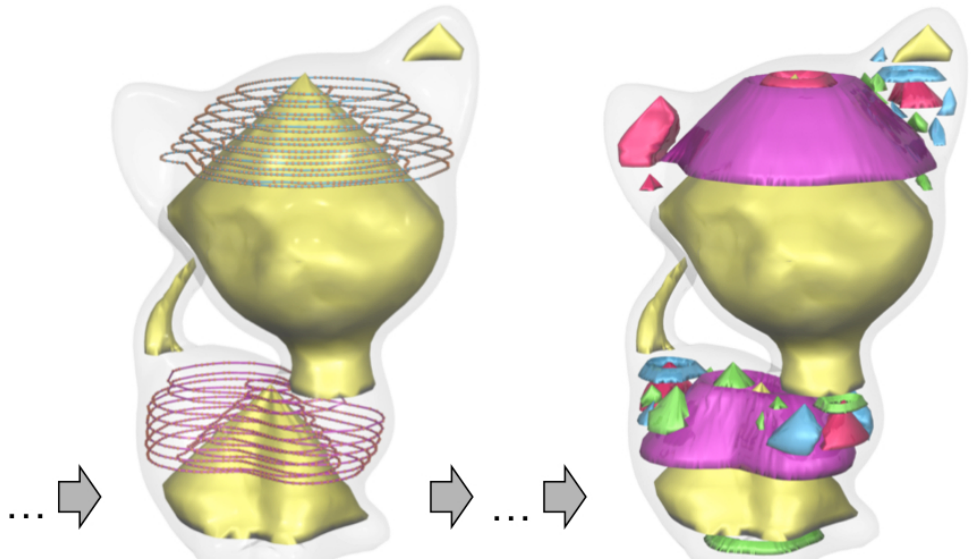


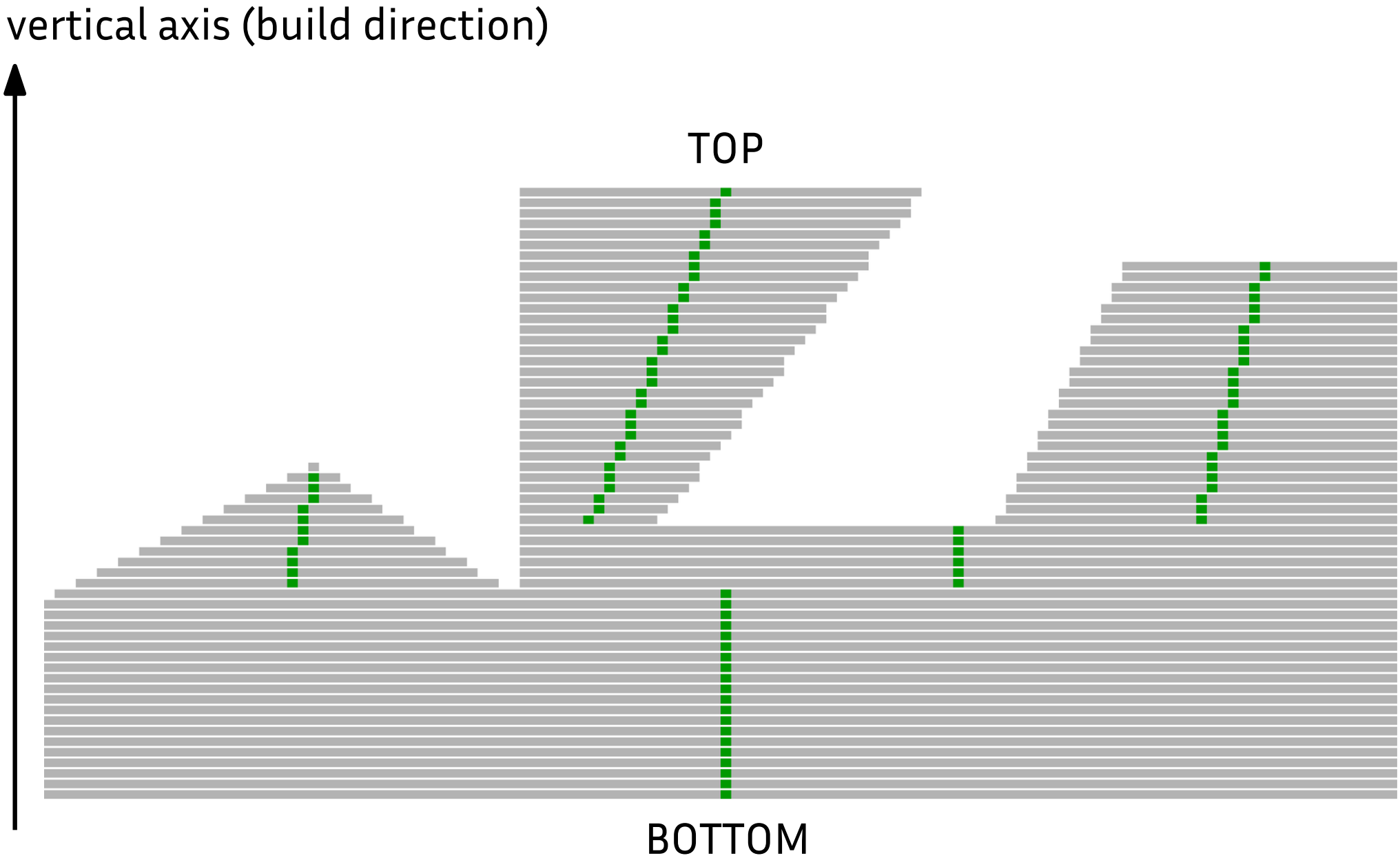
image from [Wang *et al.*]



Related Work

MakerBot *MinFill* technique (photo ©3dstartpoint.com)

Our technique, in a 2D world



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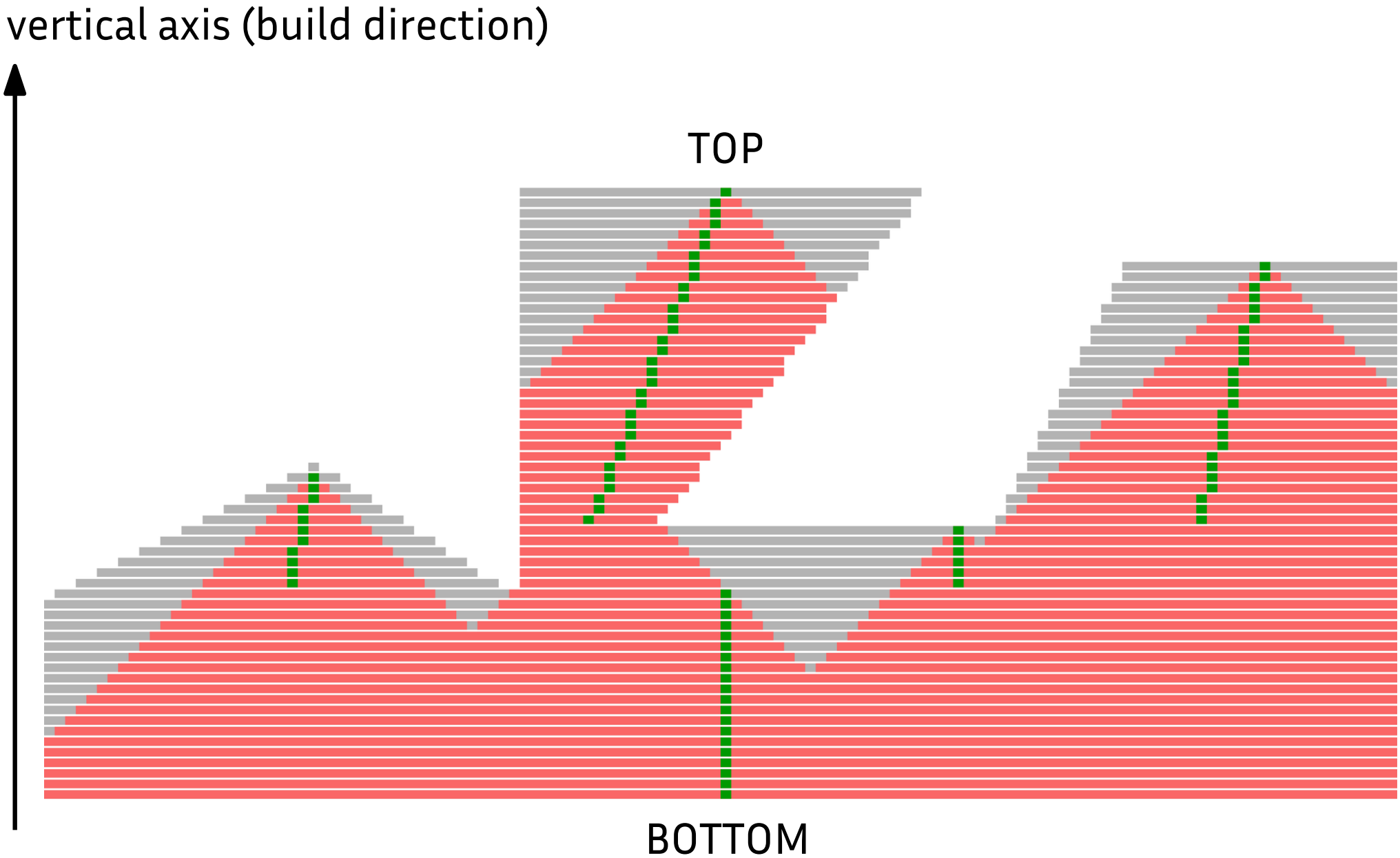

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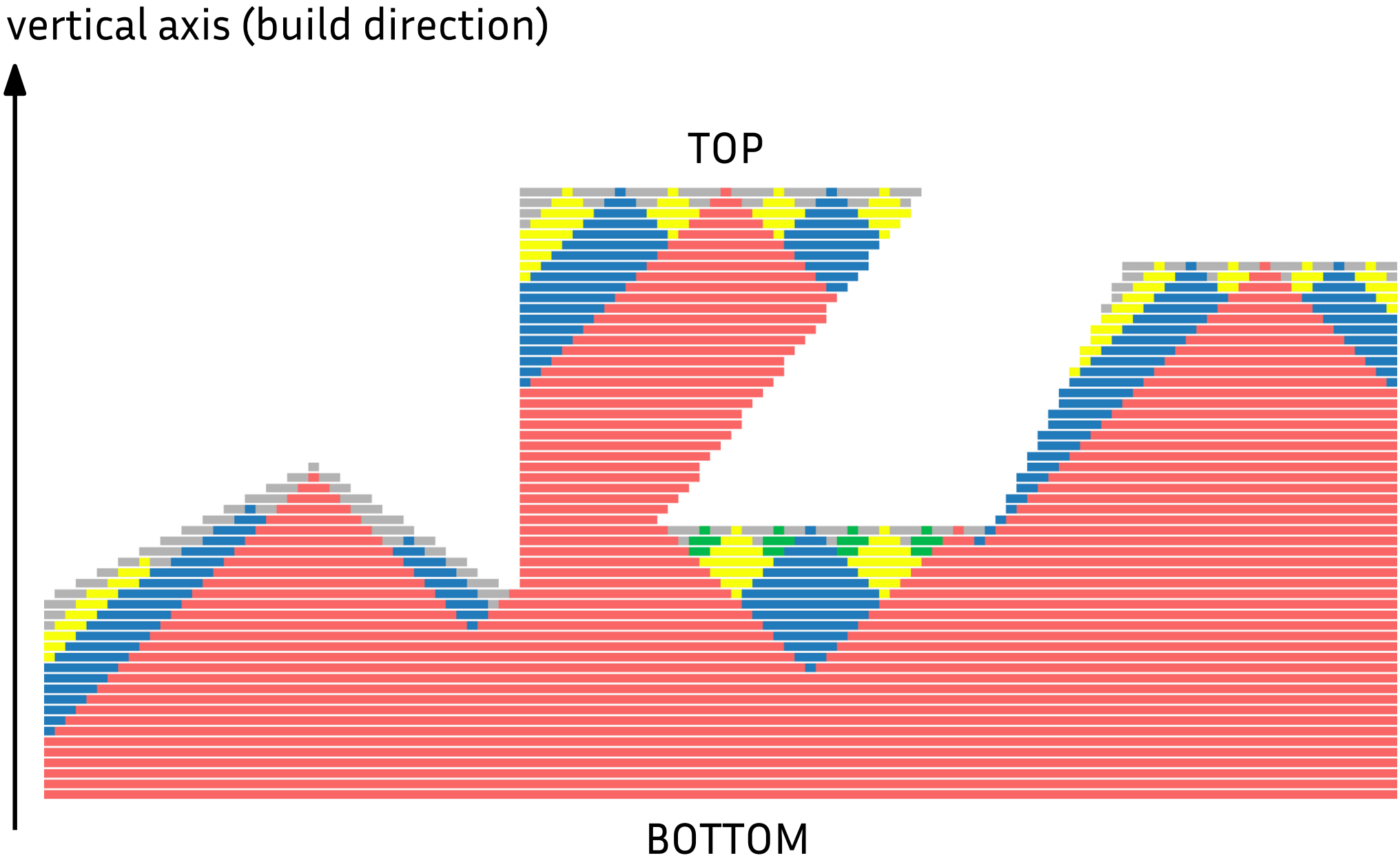

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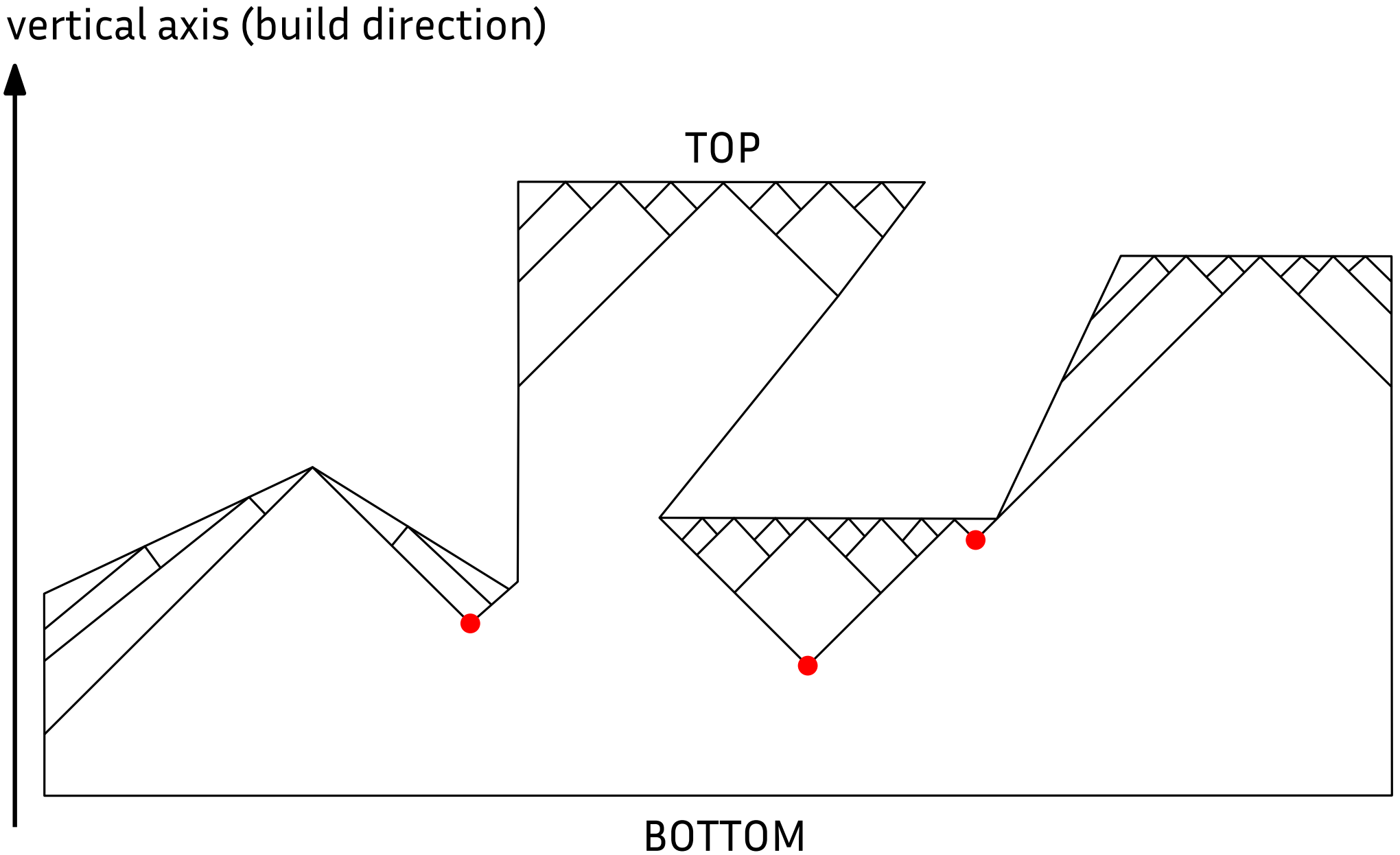
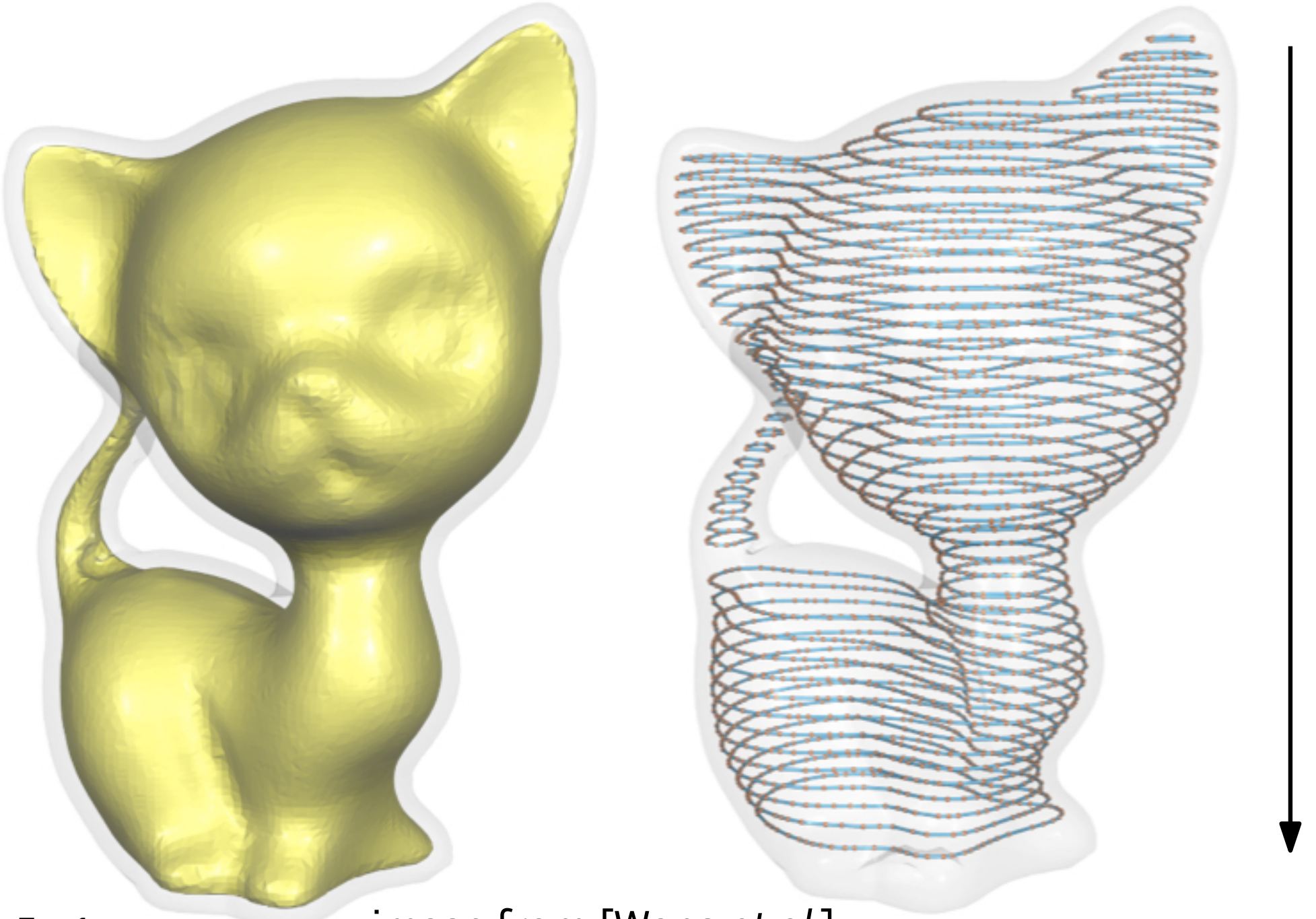


Our technique, in 3D



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Our technique, in 3D

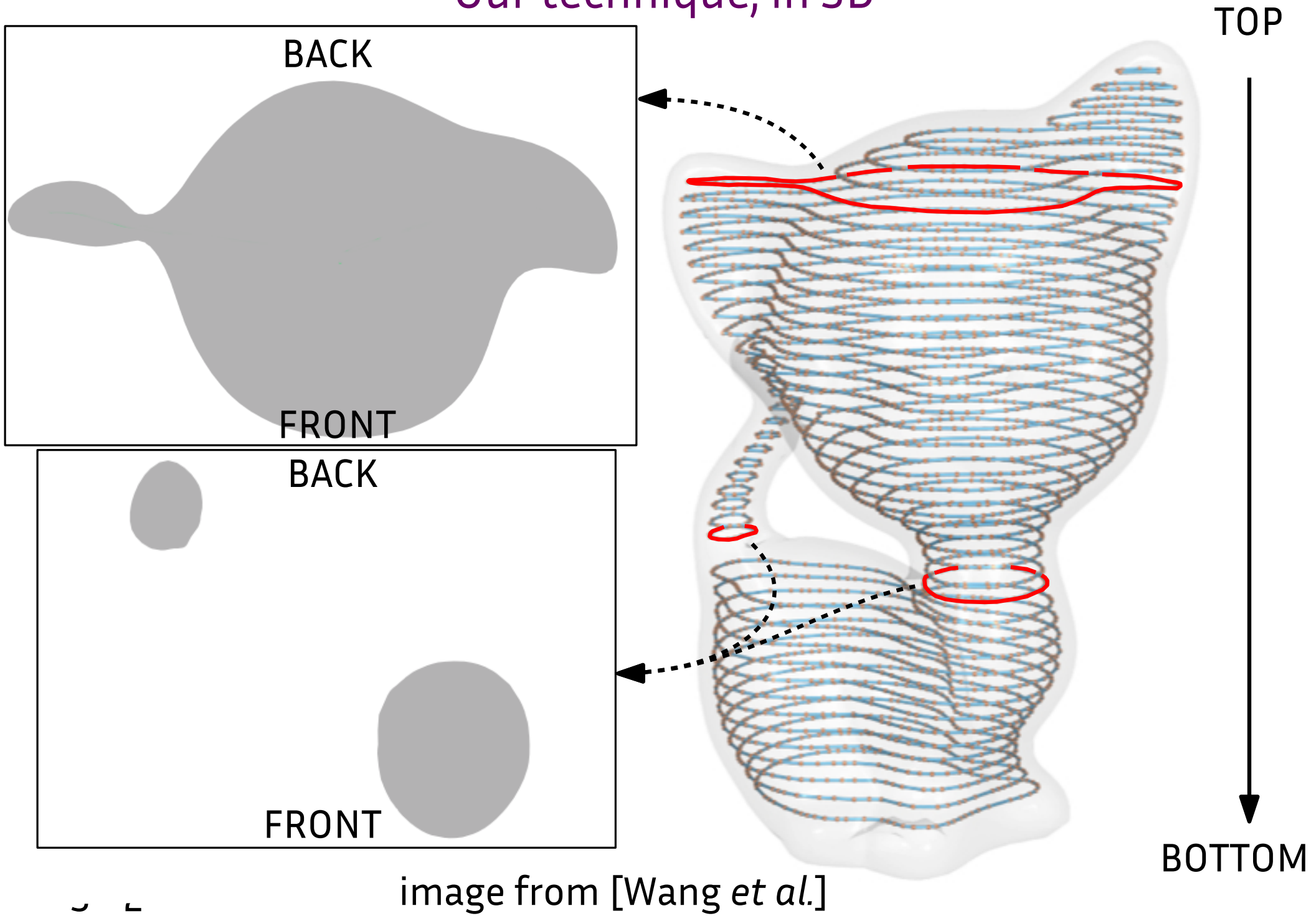
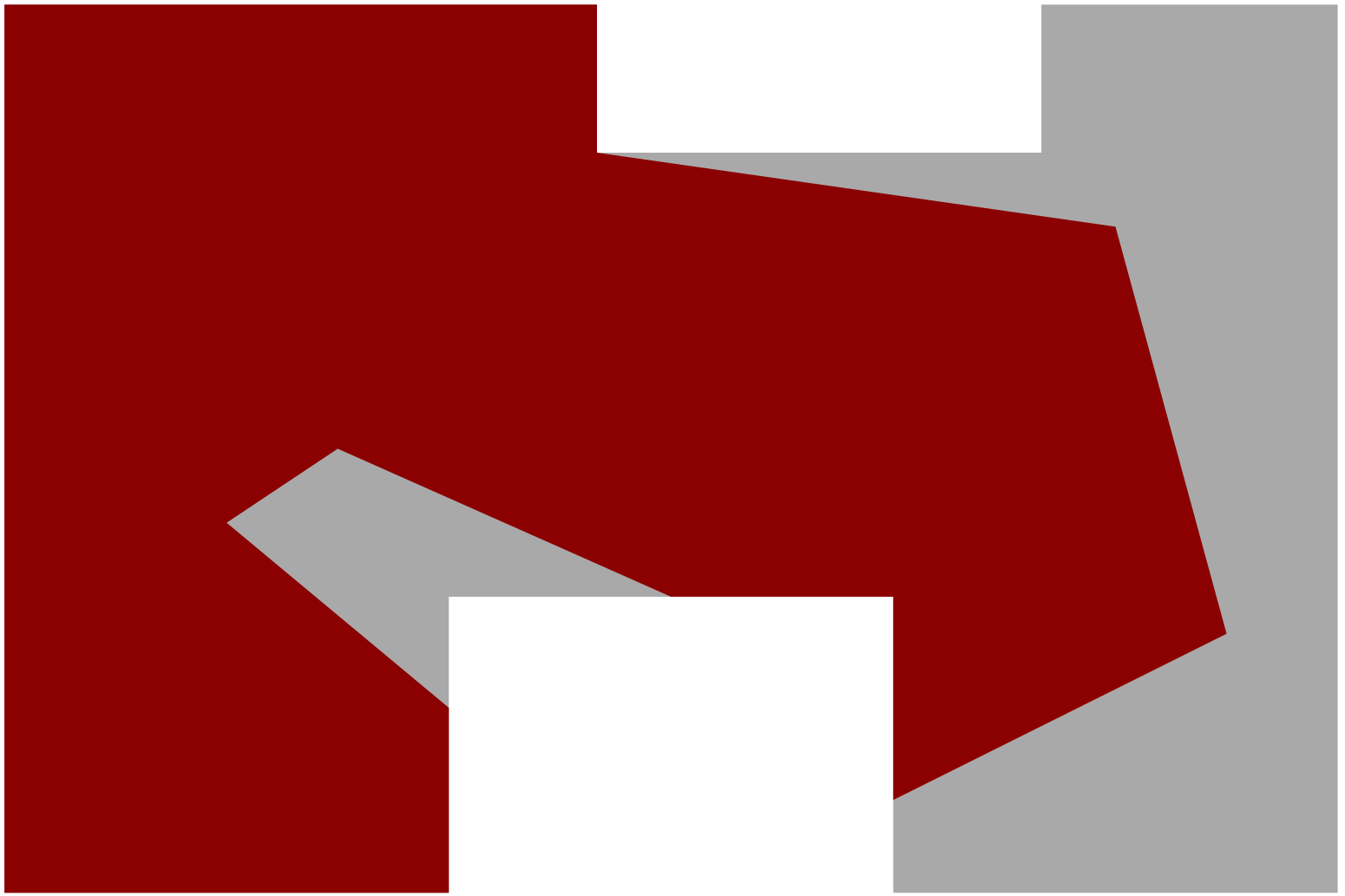


image from [Wang *et al.*]

From cavities to print-paths

- extrusion profile



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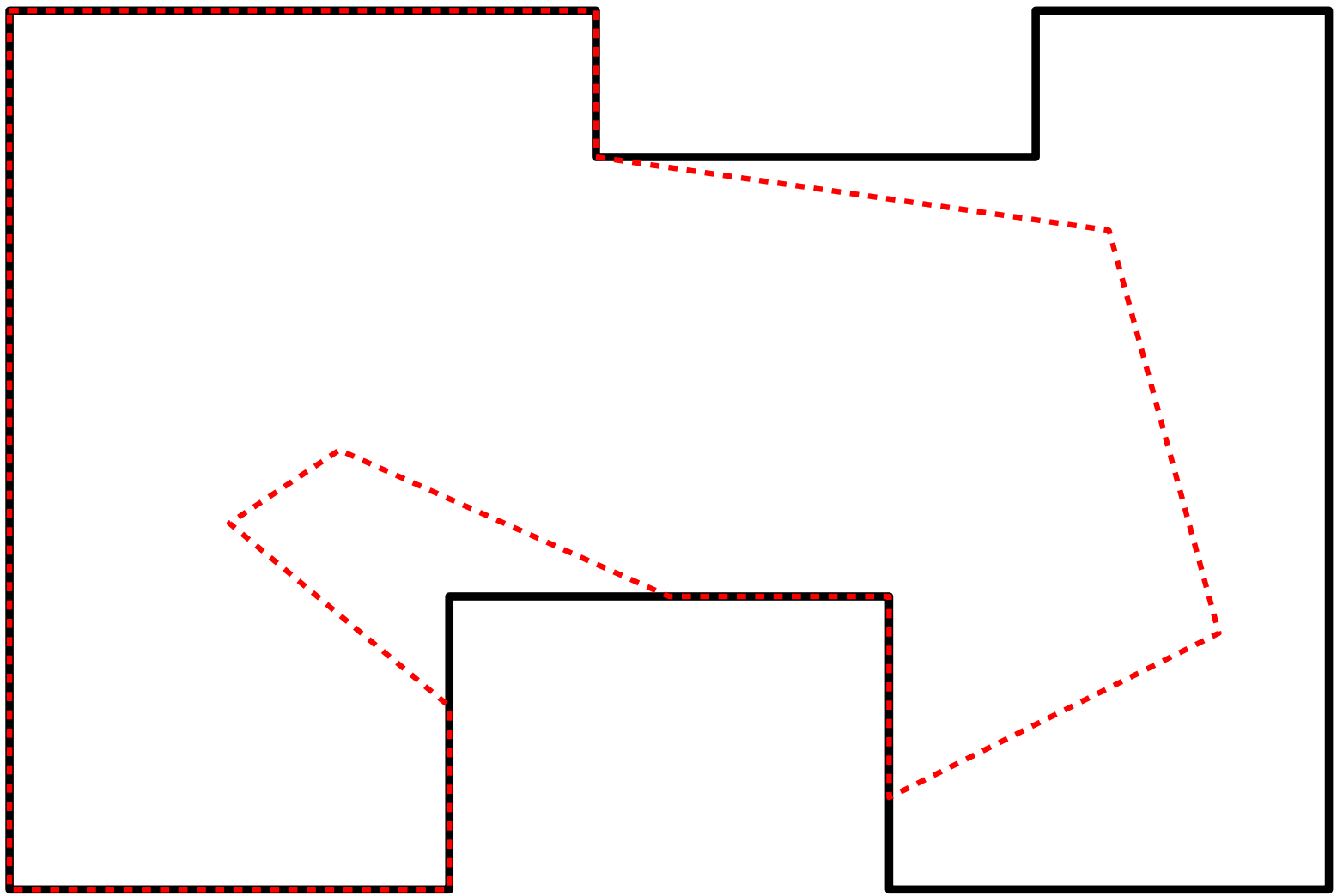

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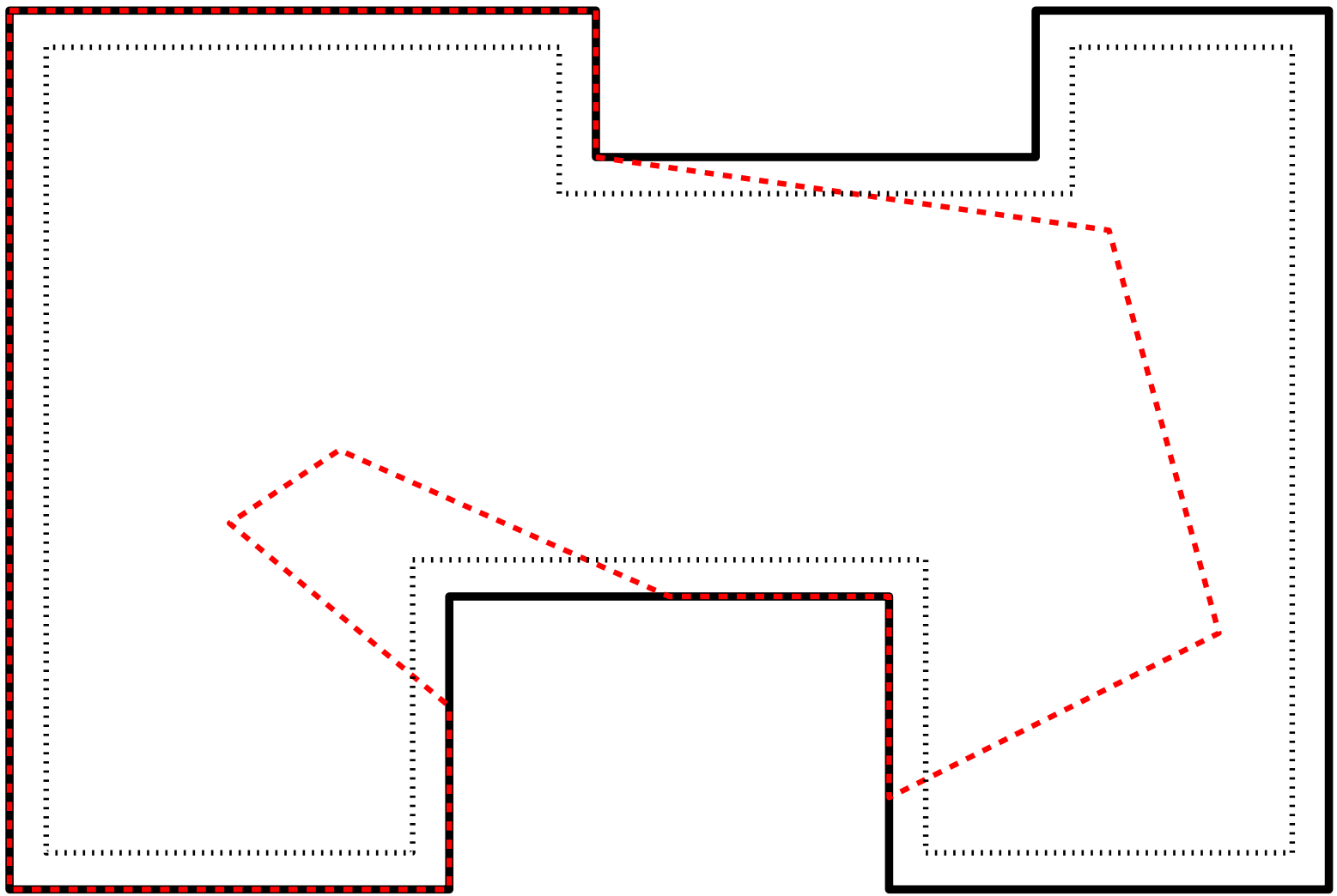

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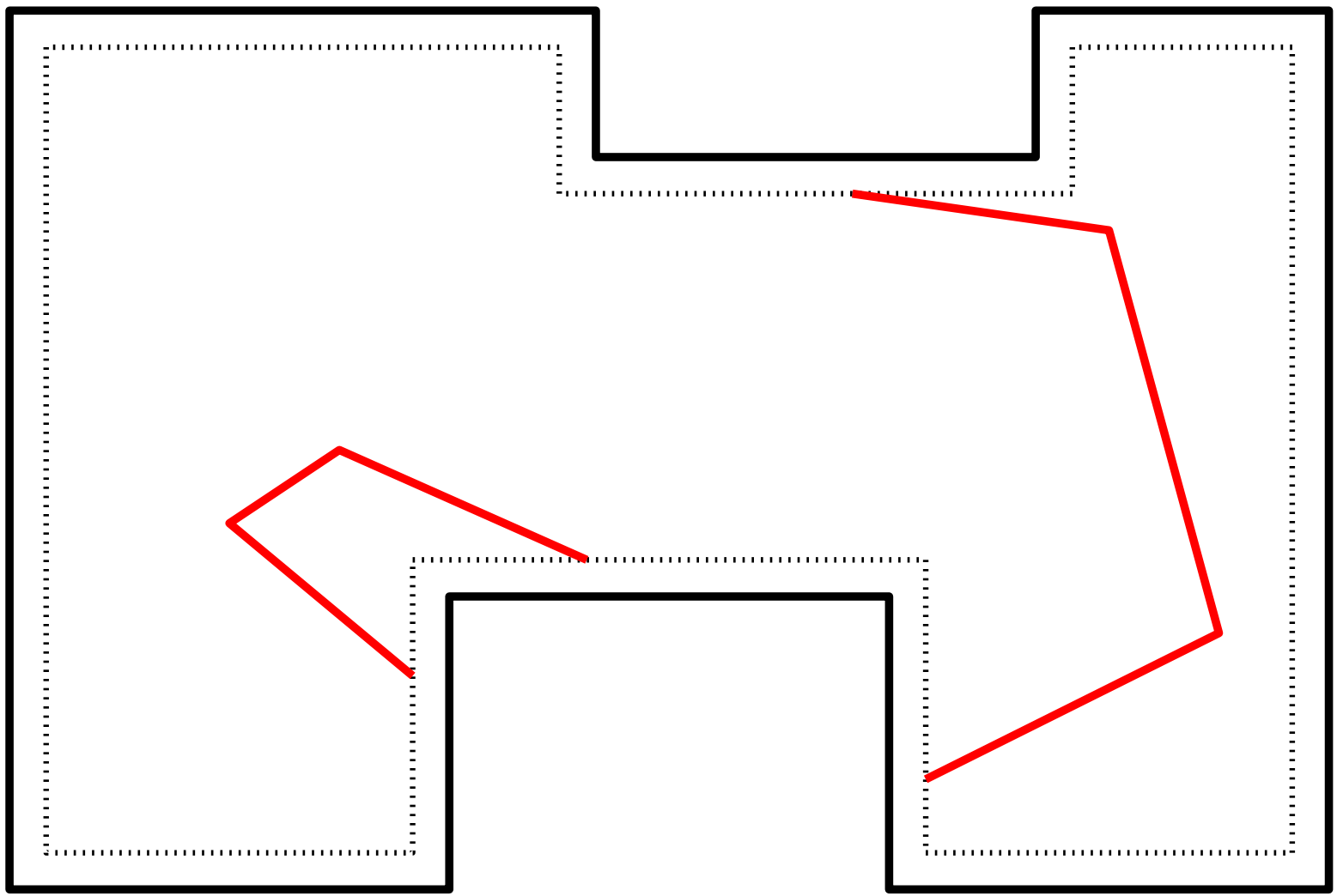

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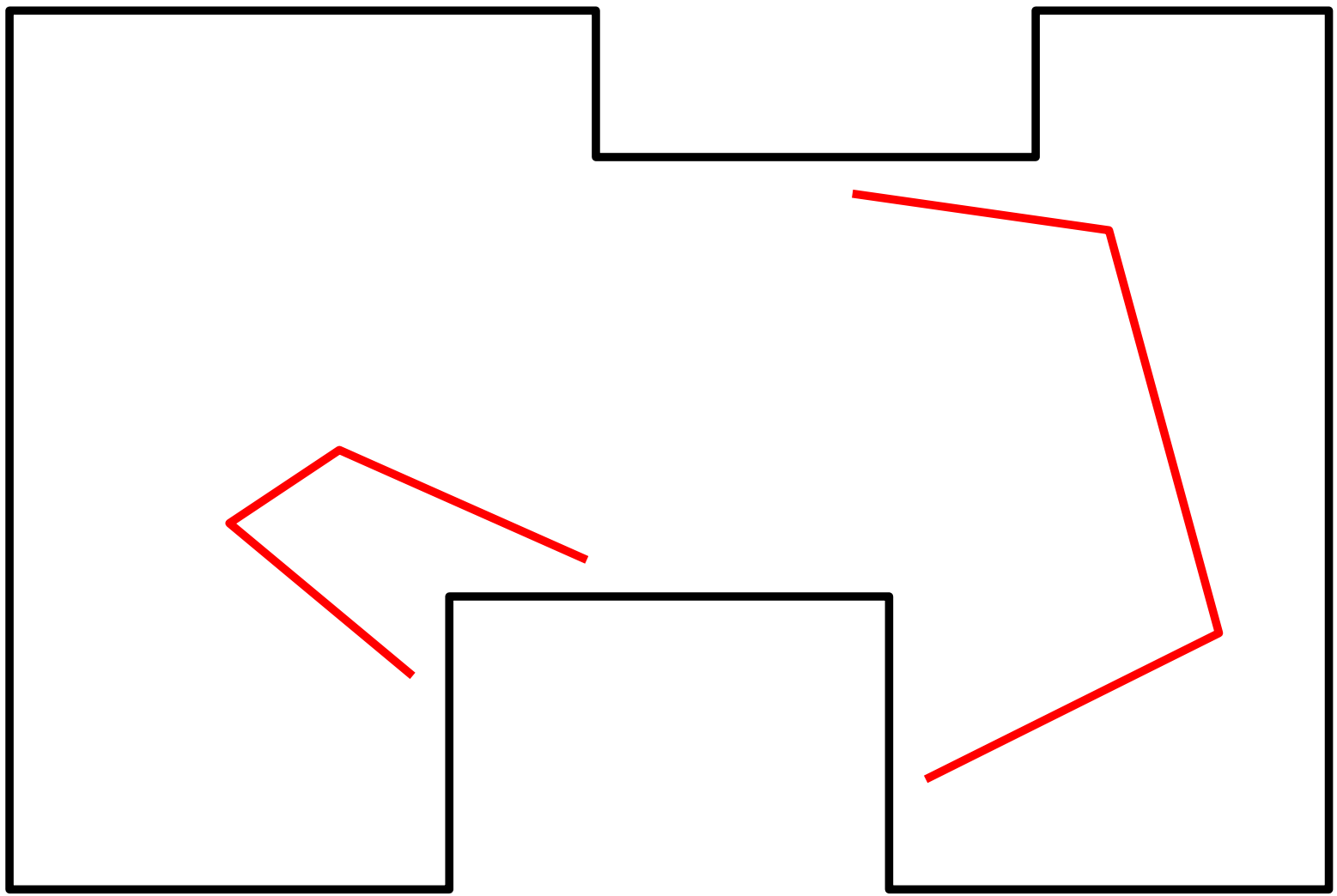

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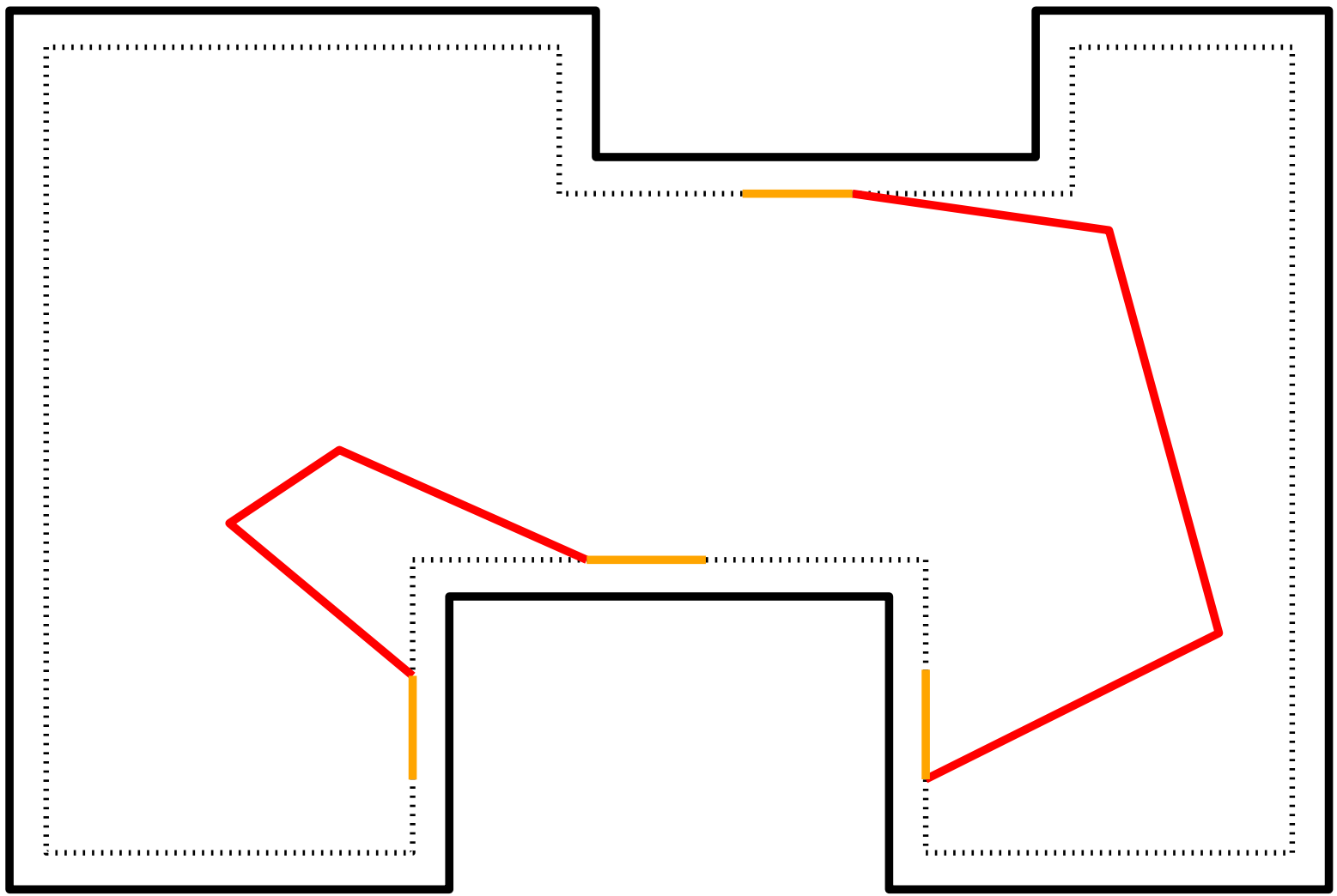

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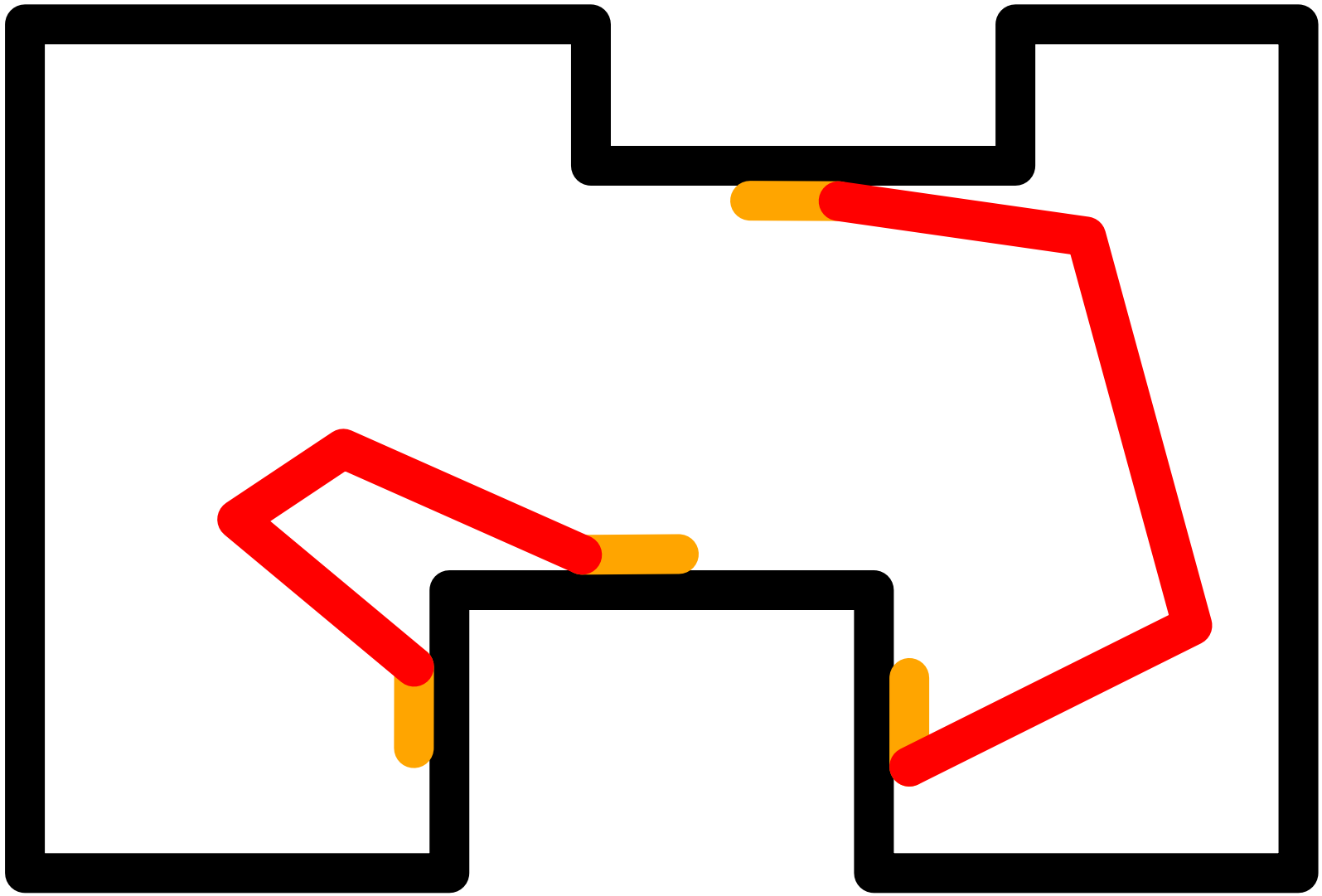

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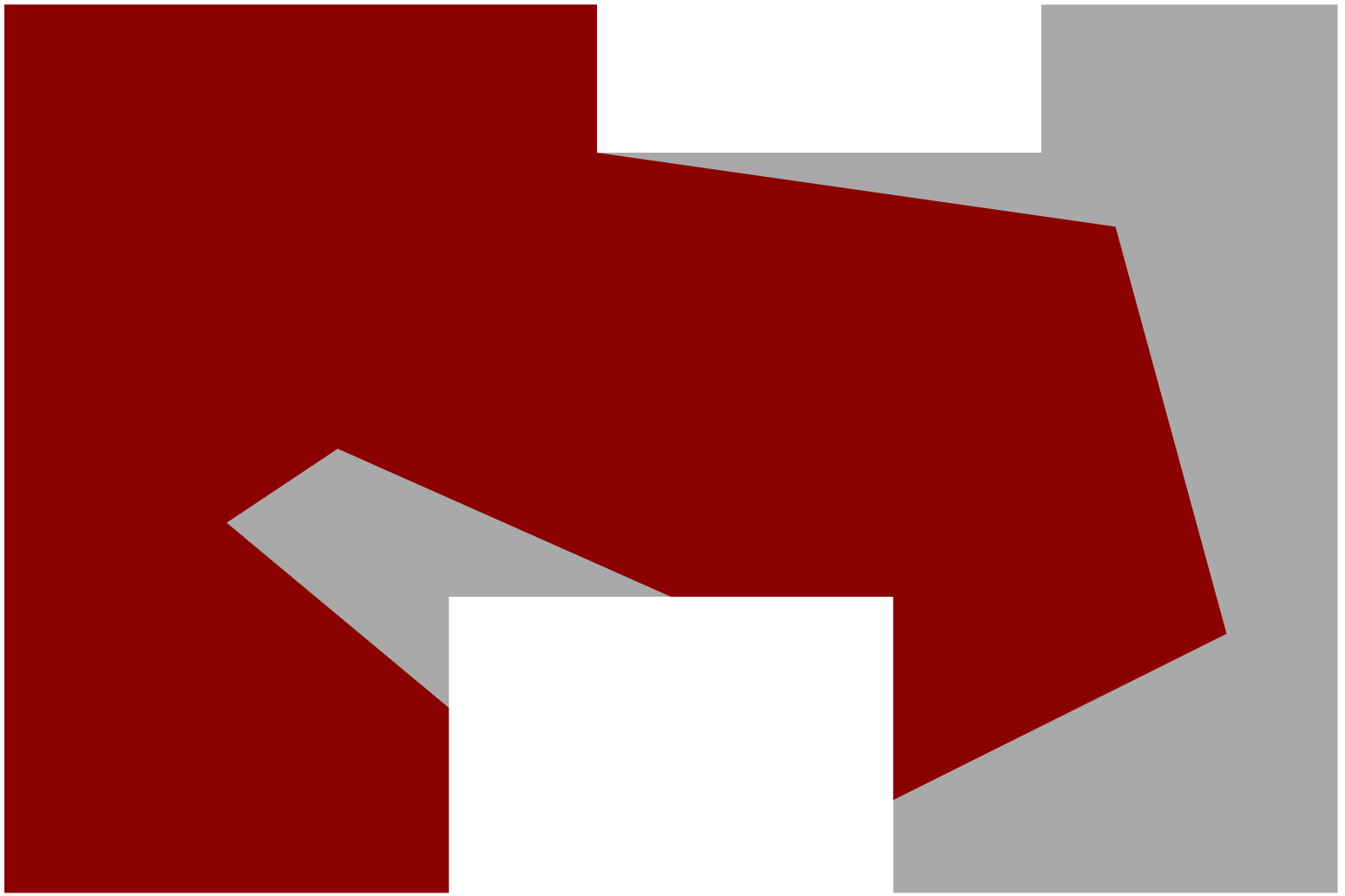
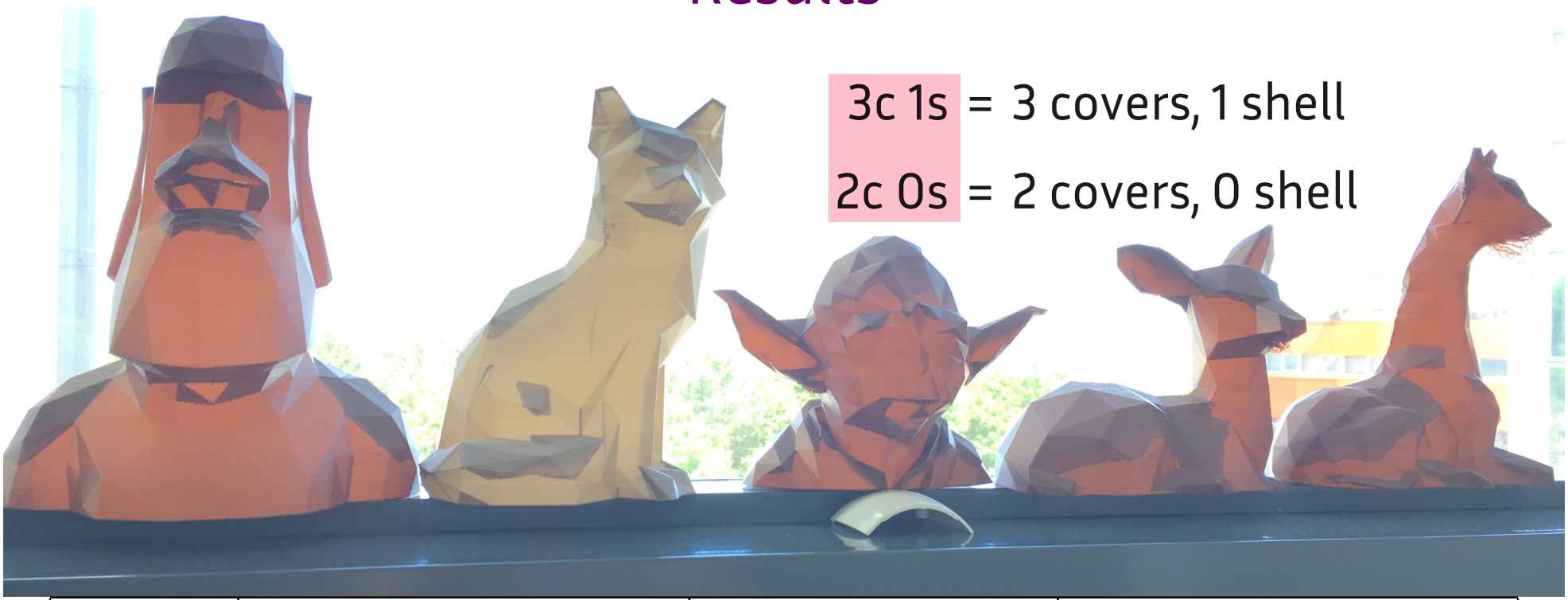


Results

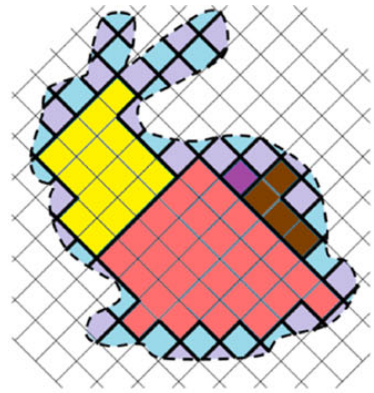


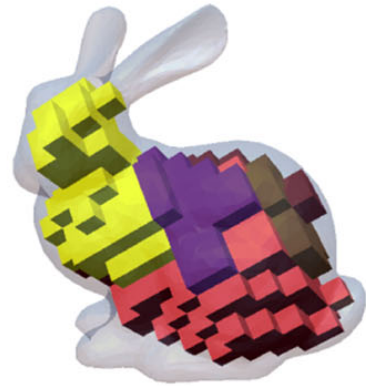
3c 1s = 3 covers, 1 shell

2c 0s = 2 covers, 0 shell

Model	Time (min.)			Volume (%)		Weight (g)		
	2c 0s	3c 1s	M2	2c 0s	3c 1s	2c 0s	3c 1s	M2
Cat	183′	223′	240′	7.77 %	11.11 %	24.4	35.5	37.6
Fawn	249′	301′	284′	7.17 %	10.17 %	31.3	47.9	45.6
Fox	192′	261′	300′	4.26 %	7.03 %	26.4	45.0	52.7
Giraffe	203′	258′	301′	6.36 %	9.73 %	25.7	42.1	49.4
Moai	279′	369′	451′	3.87 %	6.26 %	36.6	62.8	77.1
Skull	279′	368′	382′	3.35 %	5.06 %	42.6	65.5	68.9
Yoda	222′	261′	311′	5.51 %	8.37 %	24.6	38.9	51.3

Comparison with [Lee and Lee]





M2 : [Lee and Lee]

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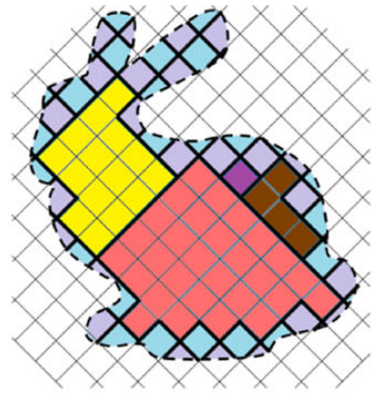

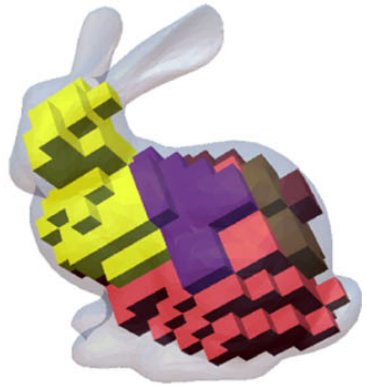

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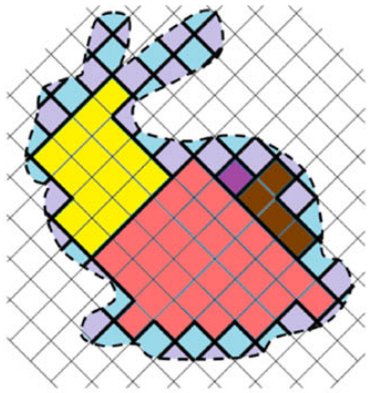

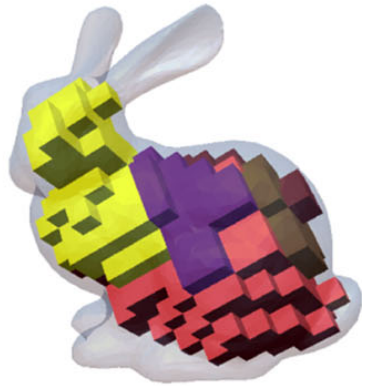

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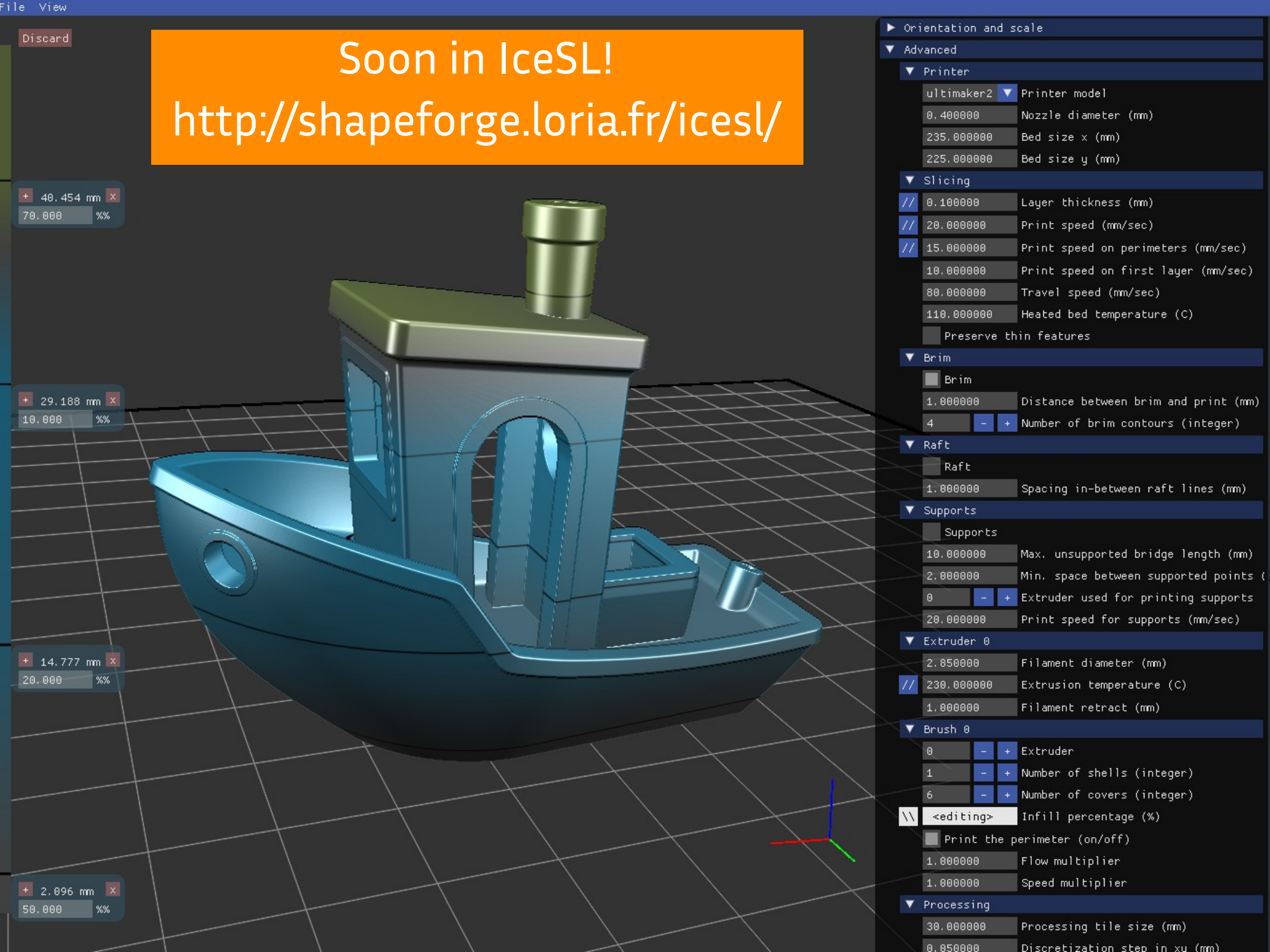
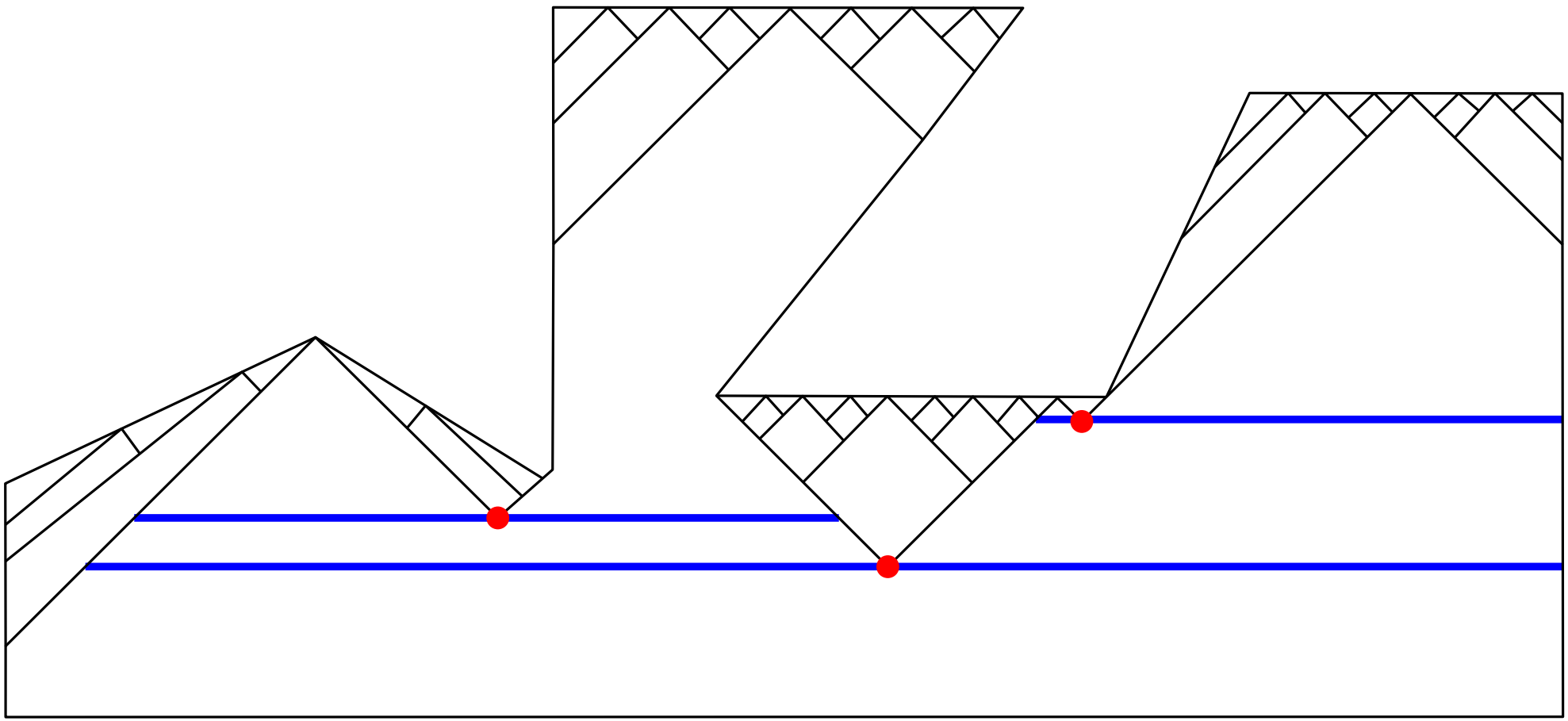
Comparison with [Wang *et al.*]

Model	Volume (%)		Processing time	
	[Wang *et al.*]	Ours	[Wang *et al.*]	Ours
Kitten	25 %	22 %	31.3 min	6.9 s (273×)
Children	47 %	37 %	59.7 min	25 s (144×)


File View
Discard
Soon in IceSL!
http://shapeforge.loria.fr/icesl/
+ 40.454 mm x
70.000 %%
+ 29.188 mm x
10.000 %%
+ 14.777 mm x
20.000 %%
+ 2.096 mm x
50.000 %%
Orientation and scale
Advanced
Printer
ultimaker2 Printer model
0.400000 Nozzle diameter (mm)
235.000000 Bed size x (mm)
225.000000 Bed size y (mm)
Slicing
// 0.100000 Layer thickness (mm)
// 20.000000 Print speed (mm/sec)
// 15.000000 Print speed on perimeters (mm/sec)
10.000000 Print speed on first layer (mm/sec)
80.000000 Travel speed (mm/sec)
110.000000 Heated bed temperature (C)
Preserve thin features
Brim
Brim
1.000000 Distance between brim and print (mm)
4 - + Number of brim contours (integer)
Raft
Raft
1.000000 Spacing in-between raft lines (mm)
Supports
Supports
10.000000 Max. unsupported bridge length (mm)
2.000000 Min. space between supported points (
0 - + Extruder used for printing supports
20.000000 Print speed for supports (mm/sec)
Extruder 0
2.850000 Filament diameter (mm)
// 230.000000 Extrusion temperature (C)
1.000000 Filament retract (mm)
Brush 0
0 - + Extruder
1 - + Number of shells (integer)
6 - + Number of covers (integer)
\\ <editing> Infill percentage (%)
Print the perimeter (on/off)
1.000000 Flow multiplier
1.000000 Speed multiplier
Processing
30.000000 Processing tile size (mm)
0.050000 Discretization step in xy (mm)

Supporting local minima



Supporting local minima