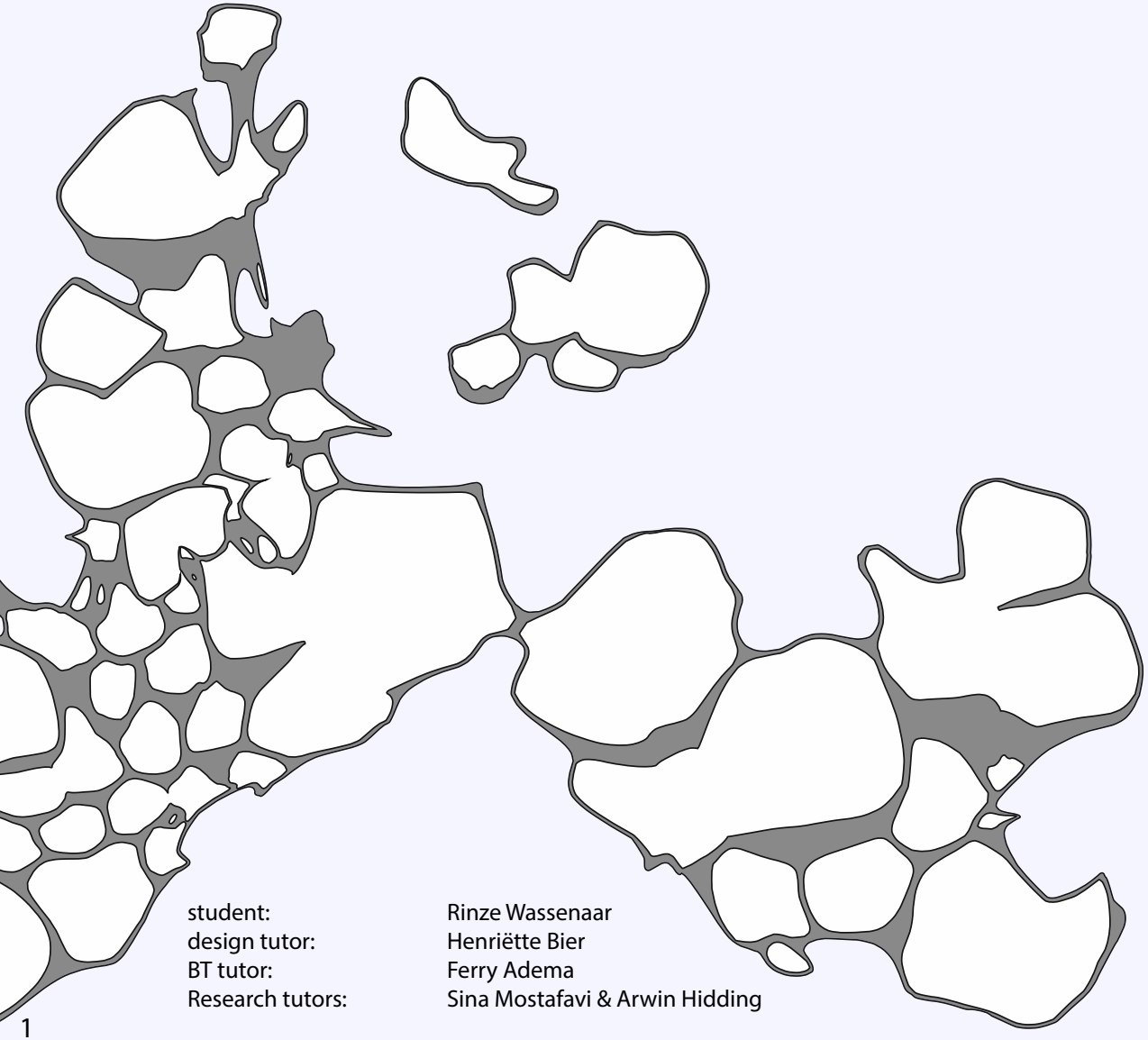
P5 Robotic Building

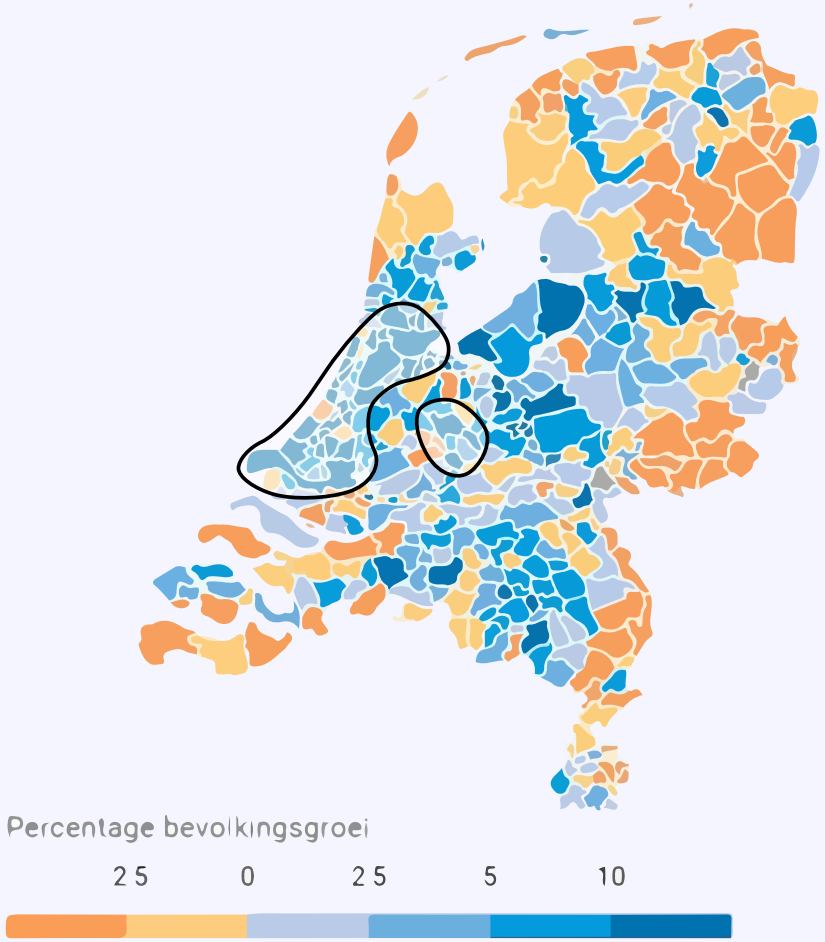
Computed Density

Inner city housing using computational design and robotic fabrication



student: Rinze Wassenaar
design tutor: Henriëtte Bier
BT tutor: Ferry Adema
Research tutors: Sina Mostafavi & Arwin Hidding

urban population increase



edited from: https://www.cbs.nl/nl-nl/nieuws/2016/37/pbl-cbs-prognose-groei-steden-zet-door

1.000.000

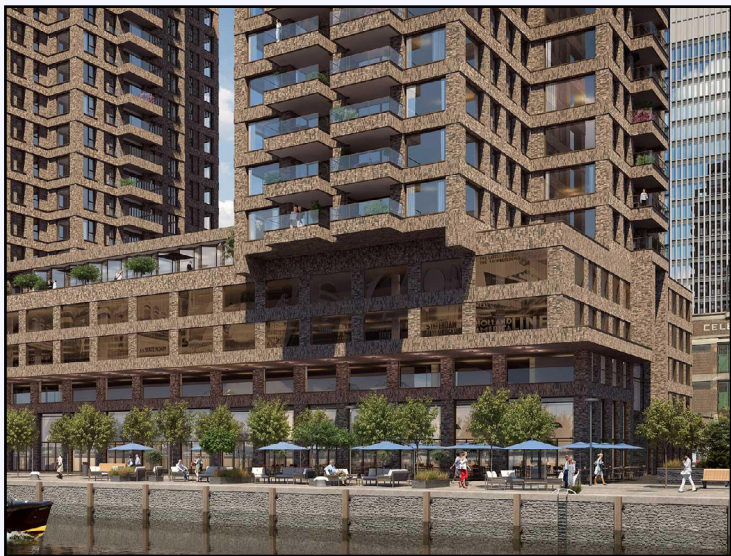












1. Are these designs suitable for inner-city environments?

2. How can **computational design and robotic manufacturing** be used to improve our inner city dwellings?

densification designs

example



irresponsible uses of space

1. spatial organization

2. building volume

3. (public + private) green space

design assignment

macro

meso

micro

densification designs

example



irresponsible uses of space

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design assignment

macro

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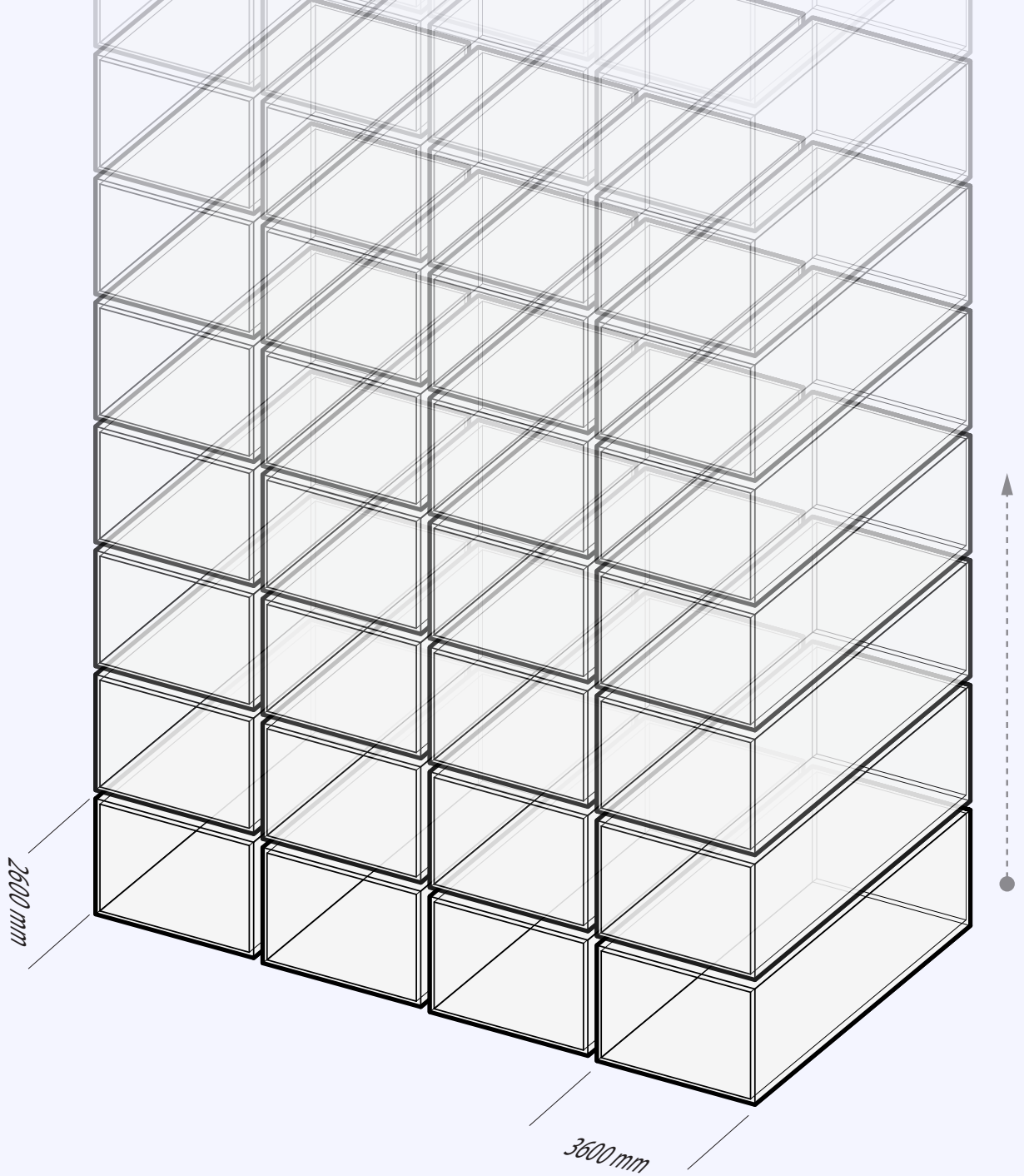
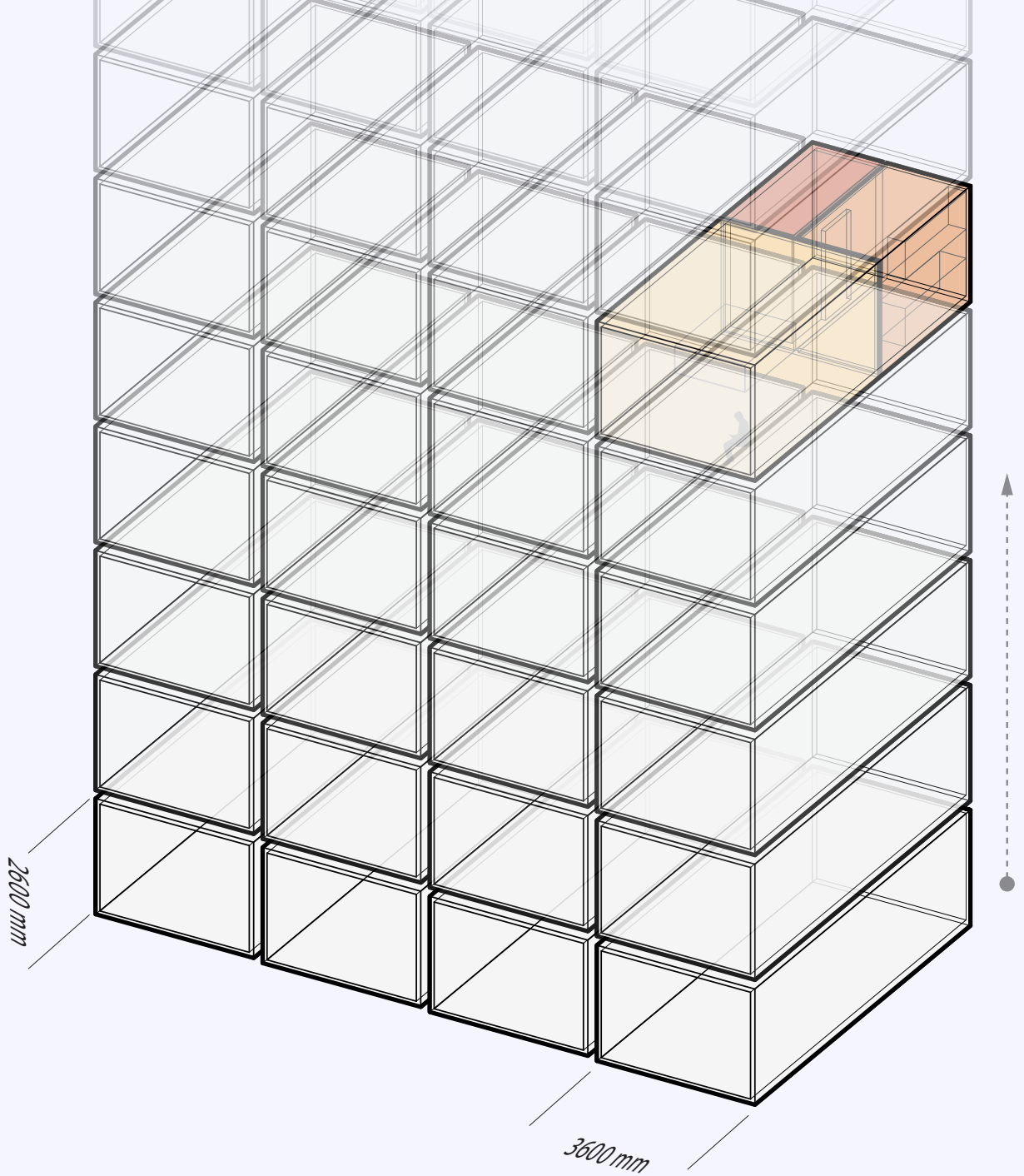
BAR 10
RottaNova




2600 mm
3600 mm


2600 mm
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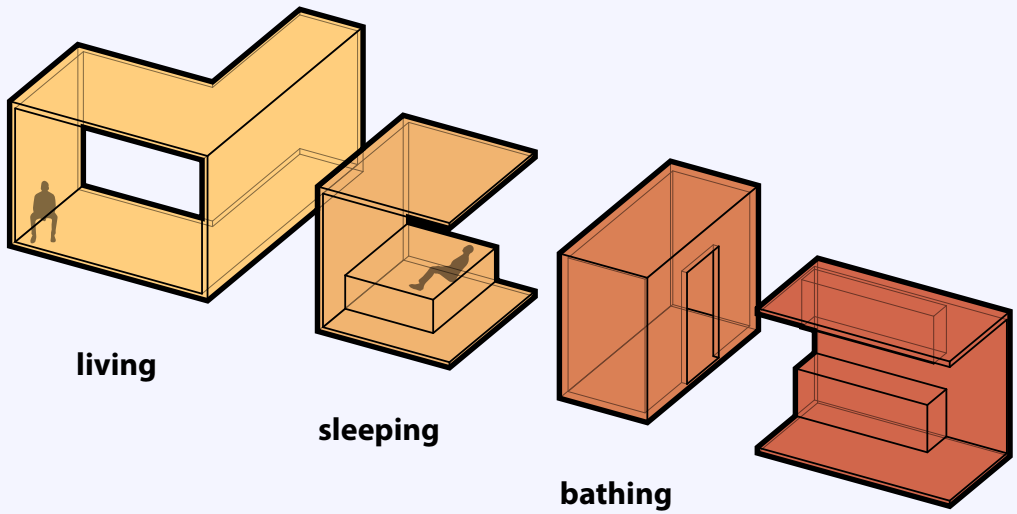
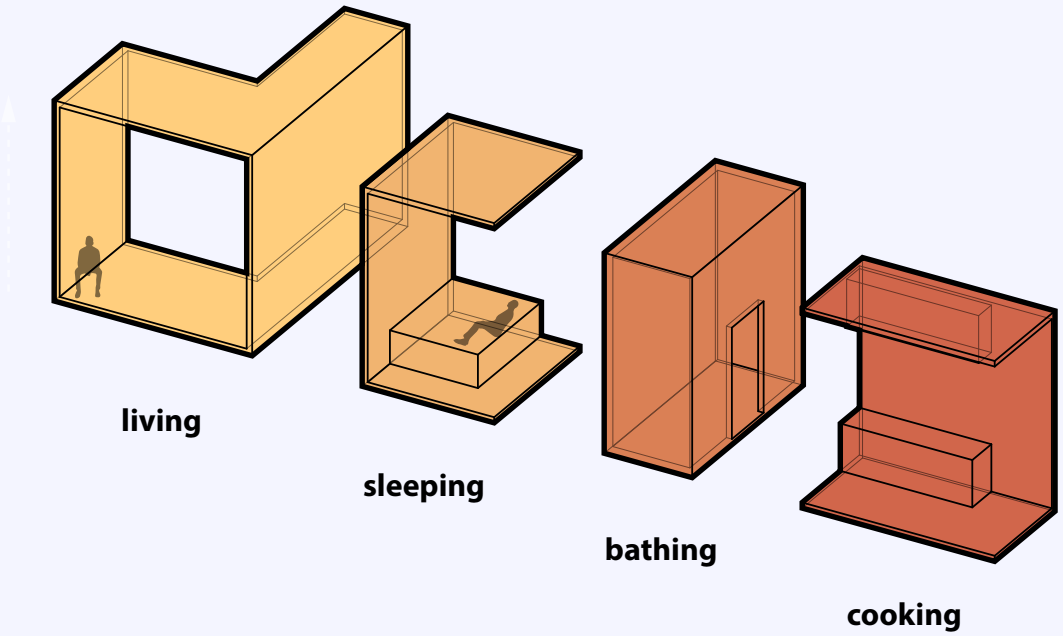
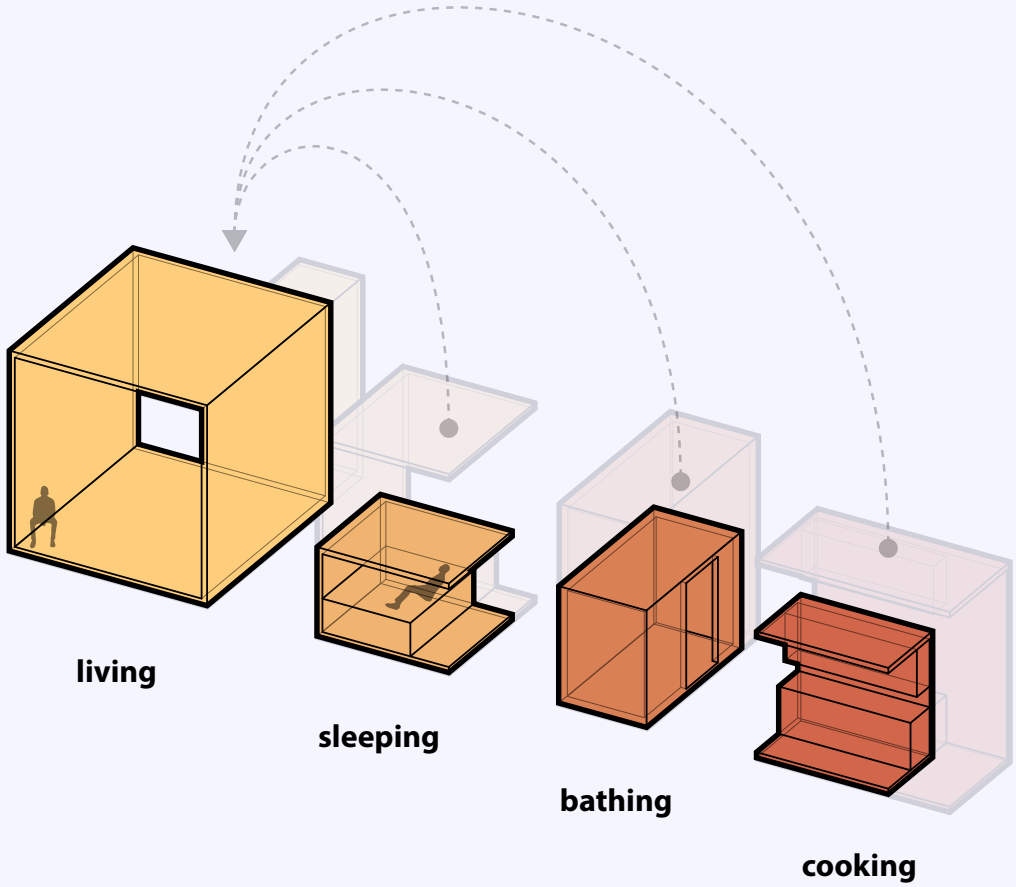

living
sleeping
bathing
cooking


living
sleeping
bathing
cooking


living
sleeping
bathing
cooking



spatious living room



traditional Dutch ‘bedstee’



MVRDV, (W)ego, DDW Eindhoven, 2017

densification designs

example



irresponsible uses of space

1. spatial organization

2. building volume

3. (public + private) green space

design assignment

macro

meso

micro



N

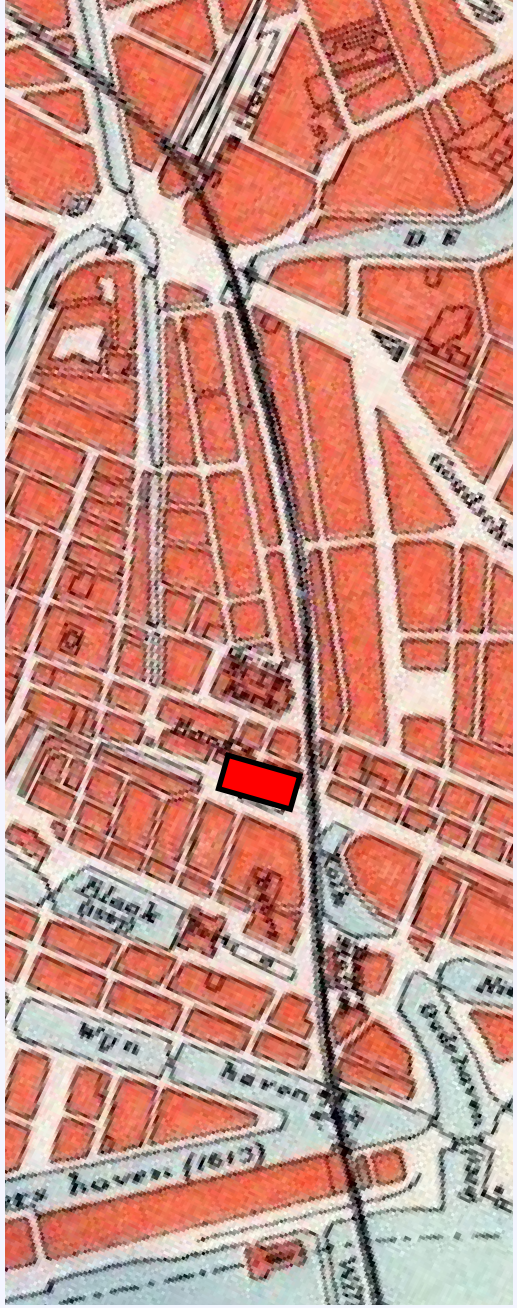
1000m



ca. 1340



1694

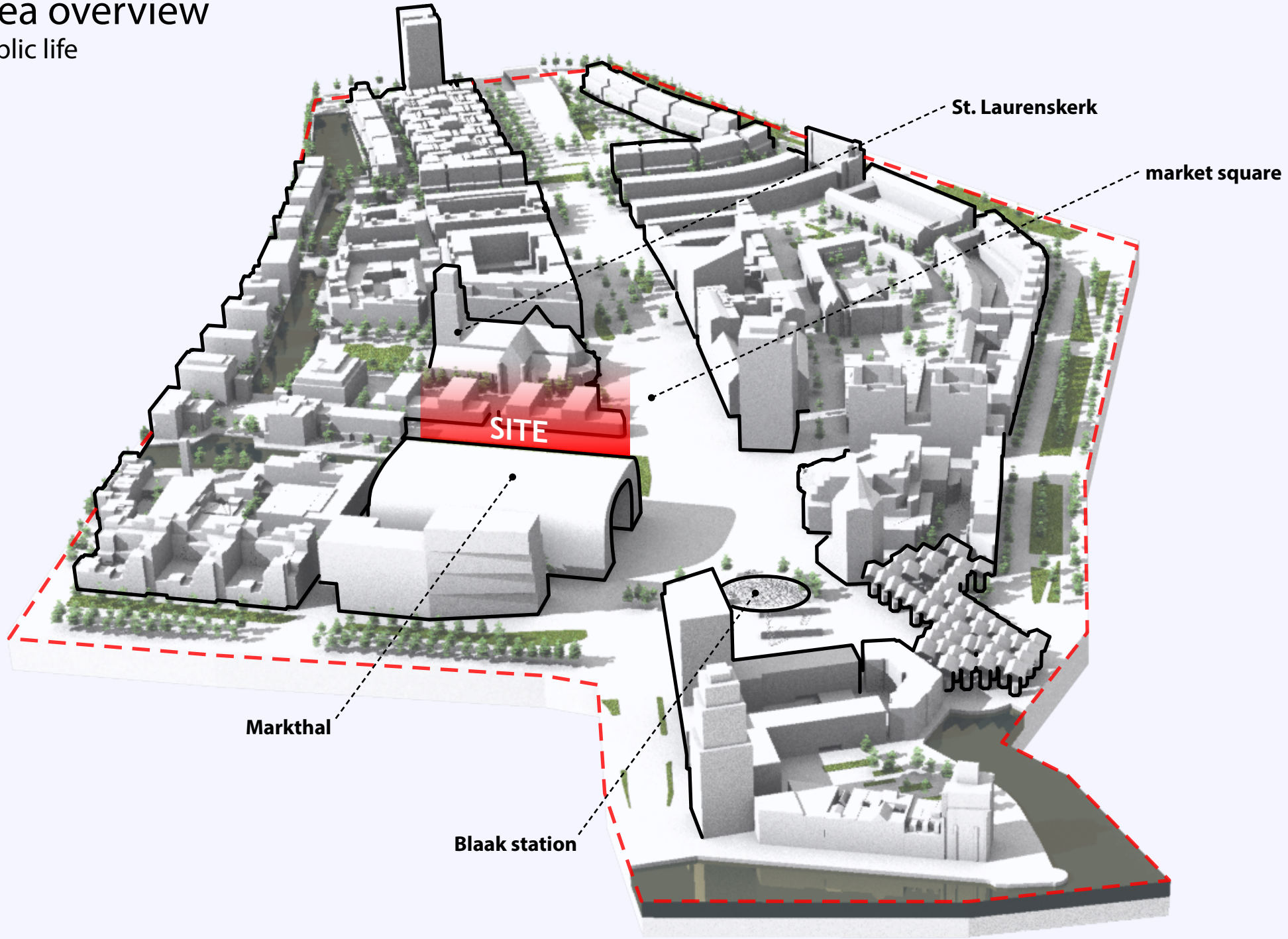


1912



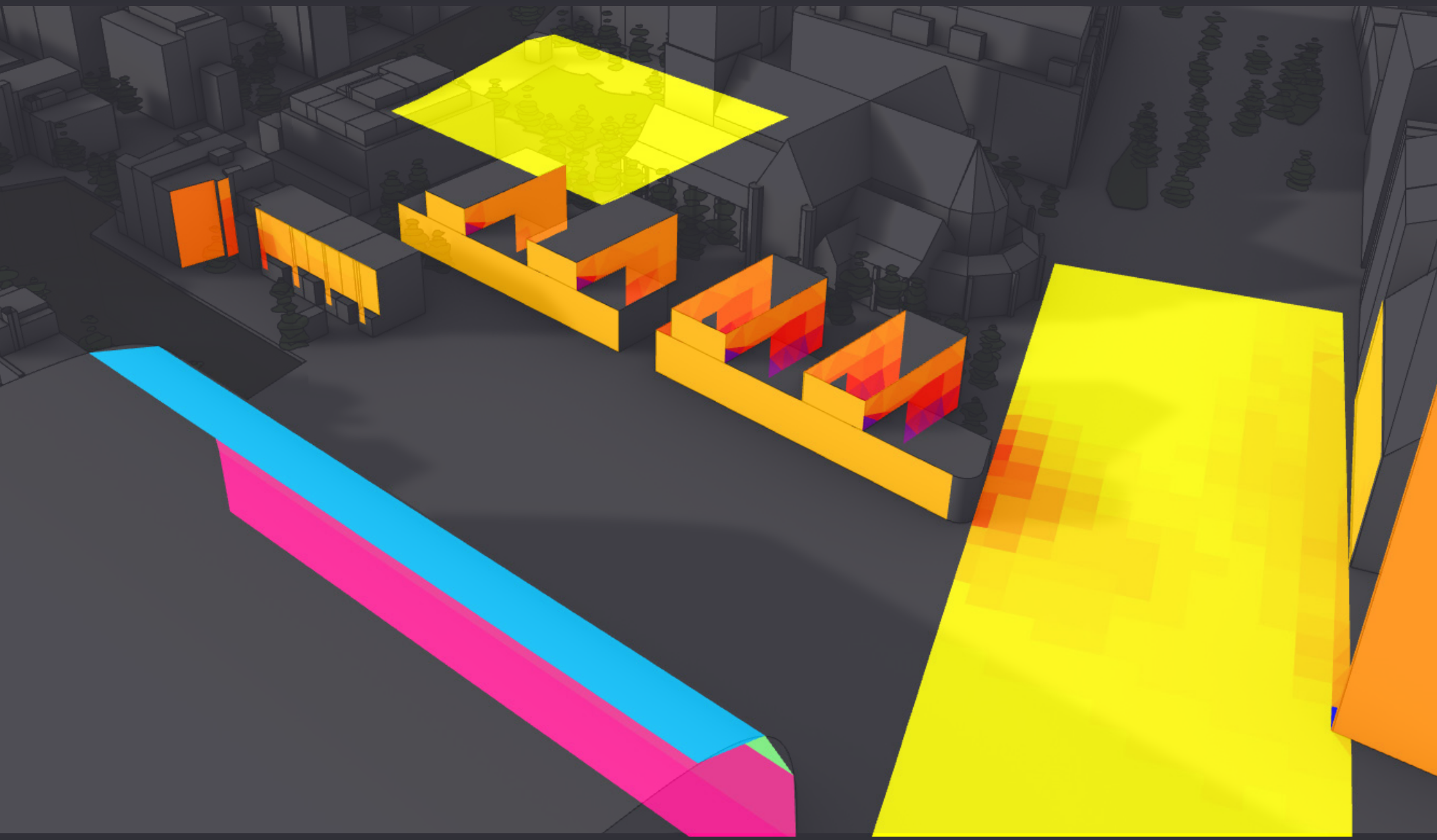
1960s

area overview
public life



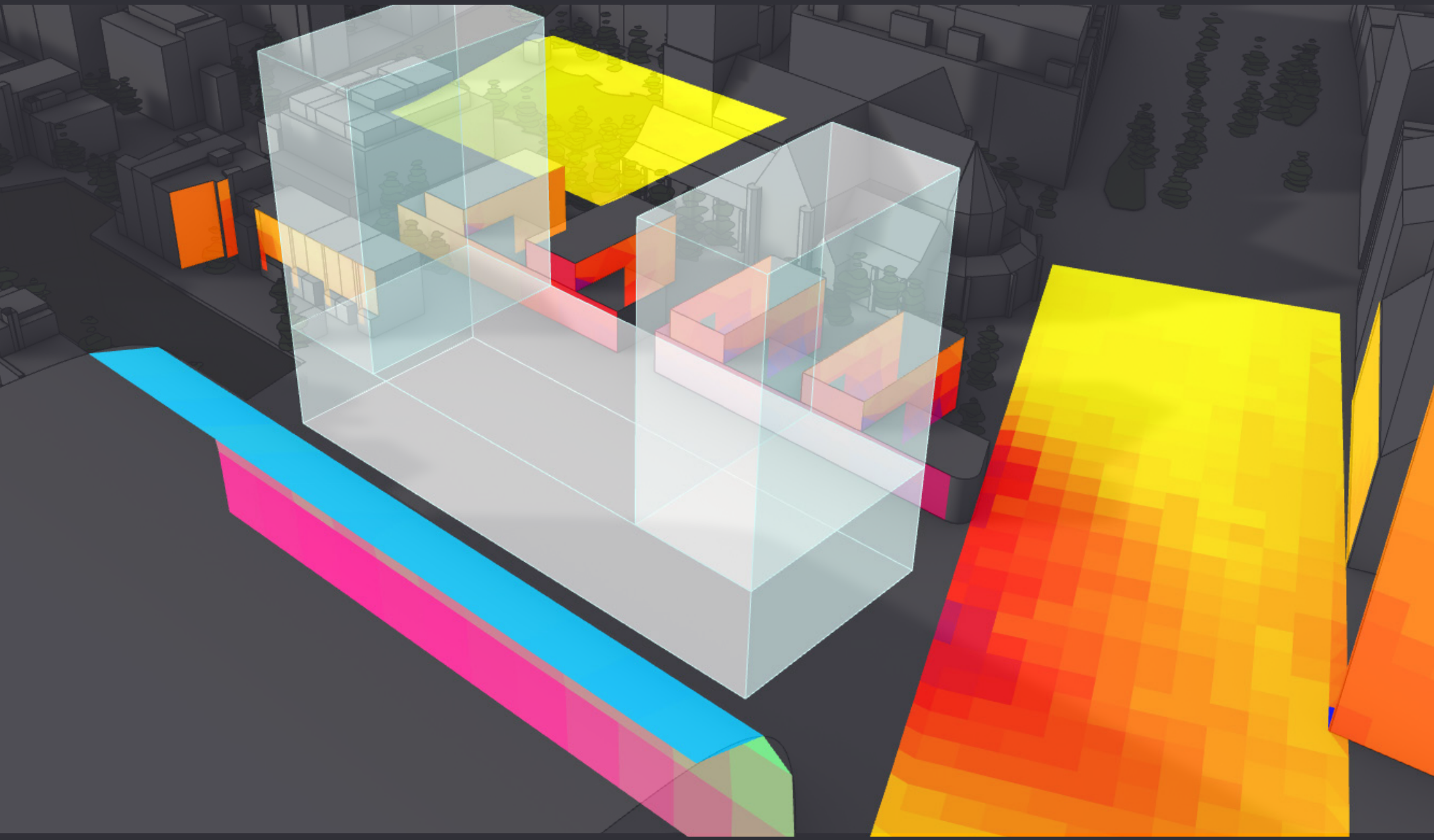
direct solar access (present)

[10:00-18:00, 21-3 until 21-9]



direct solar access - after design intervention

[10:00-18:00, 21-3 until 21-9]



densification designs

example



irresponsible uses of space

1. spatial organization

2. building volume

3. (public + private) green space

design assignment

macro

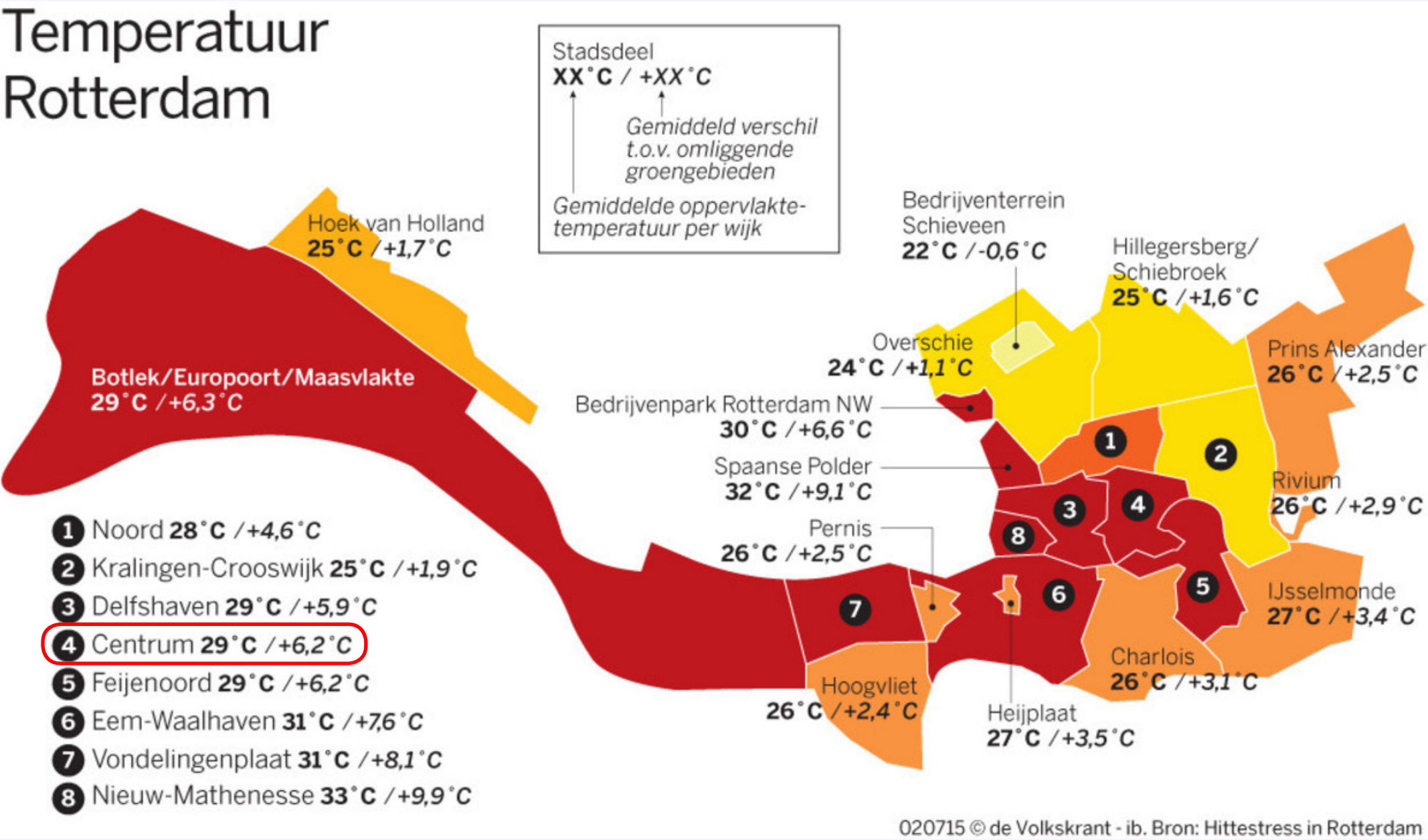
meso

micro

site current situation



urban heat island effect



densification designs

example



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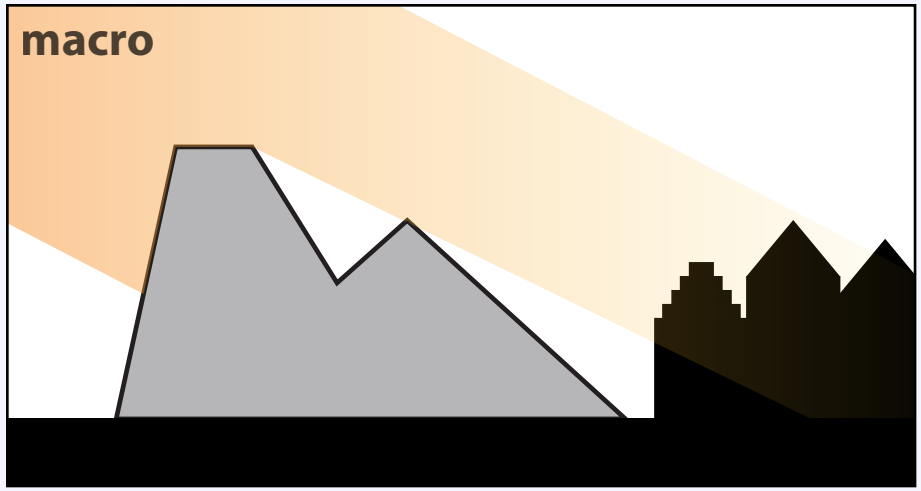
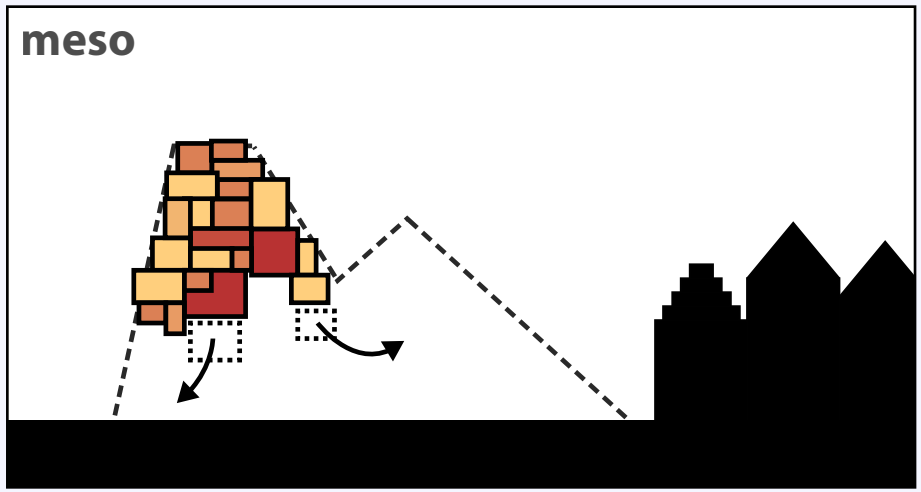
macro

meso

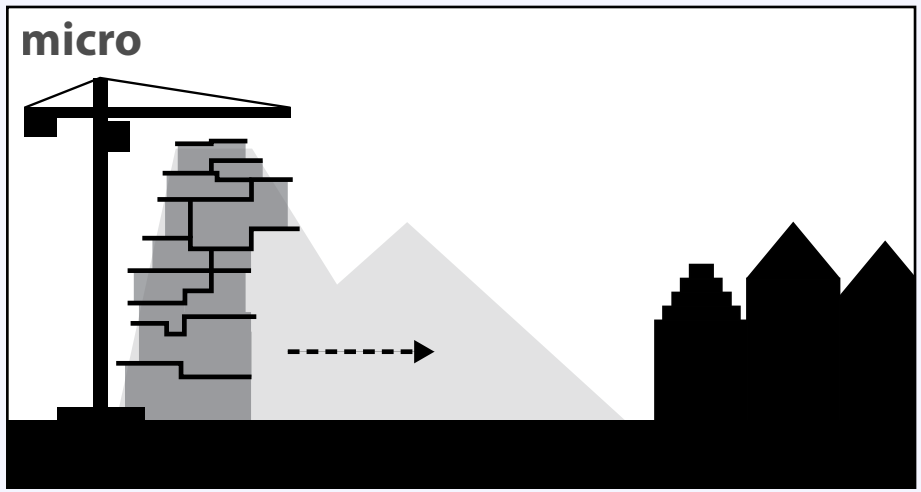
micro



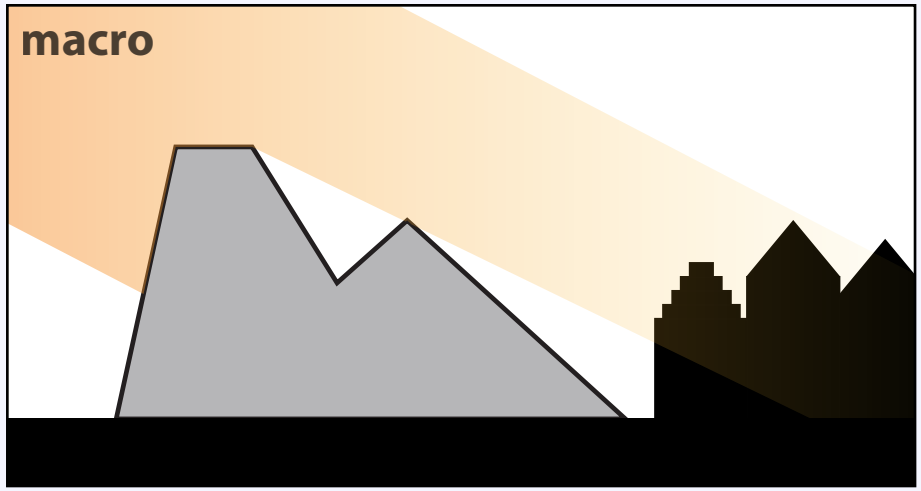
Bounding volume based on solar access of adjacent buildings/public spaces.



Generative spatial organization with differently sized apartment spaces.



Mass-customizible structural system.



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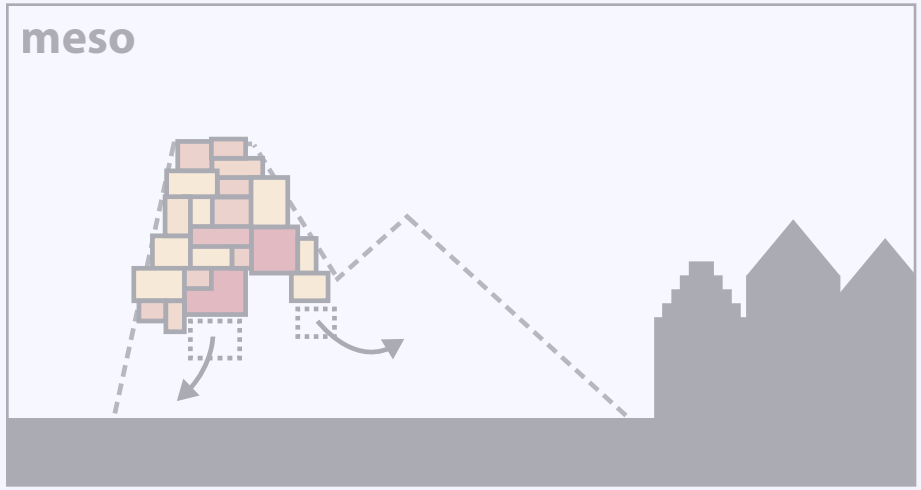

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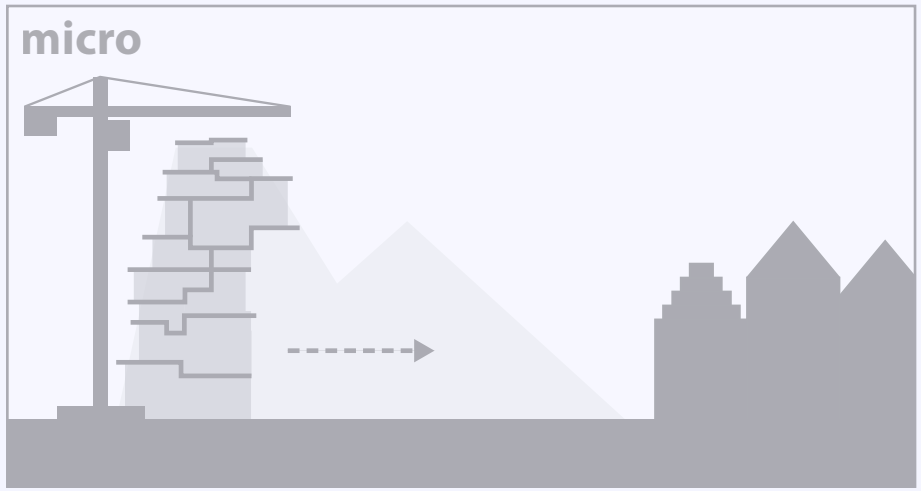


Mass-customizible structural system.

goal

limit shading increase on nearby buildings & squares



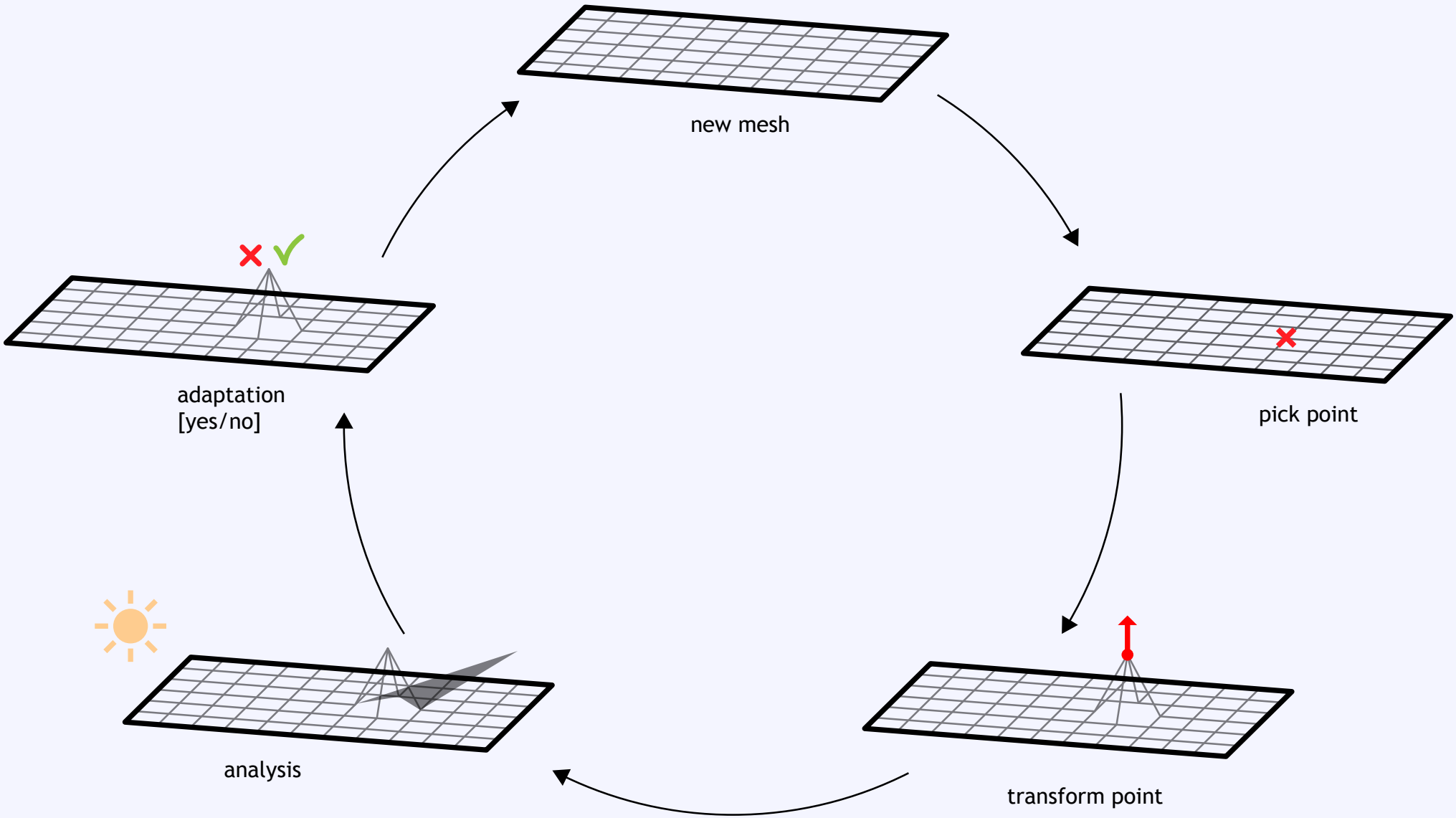
markthal
< 20% skyview reduction/day

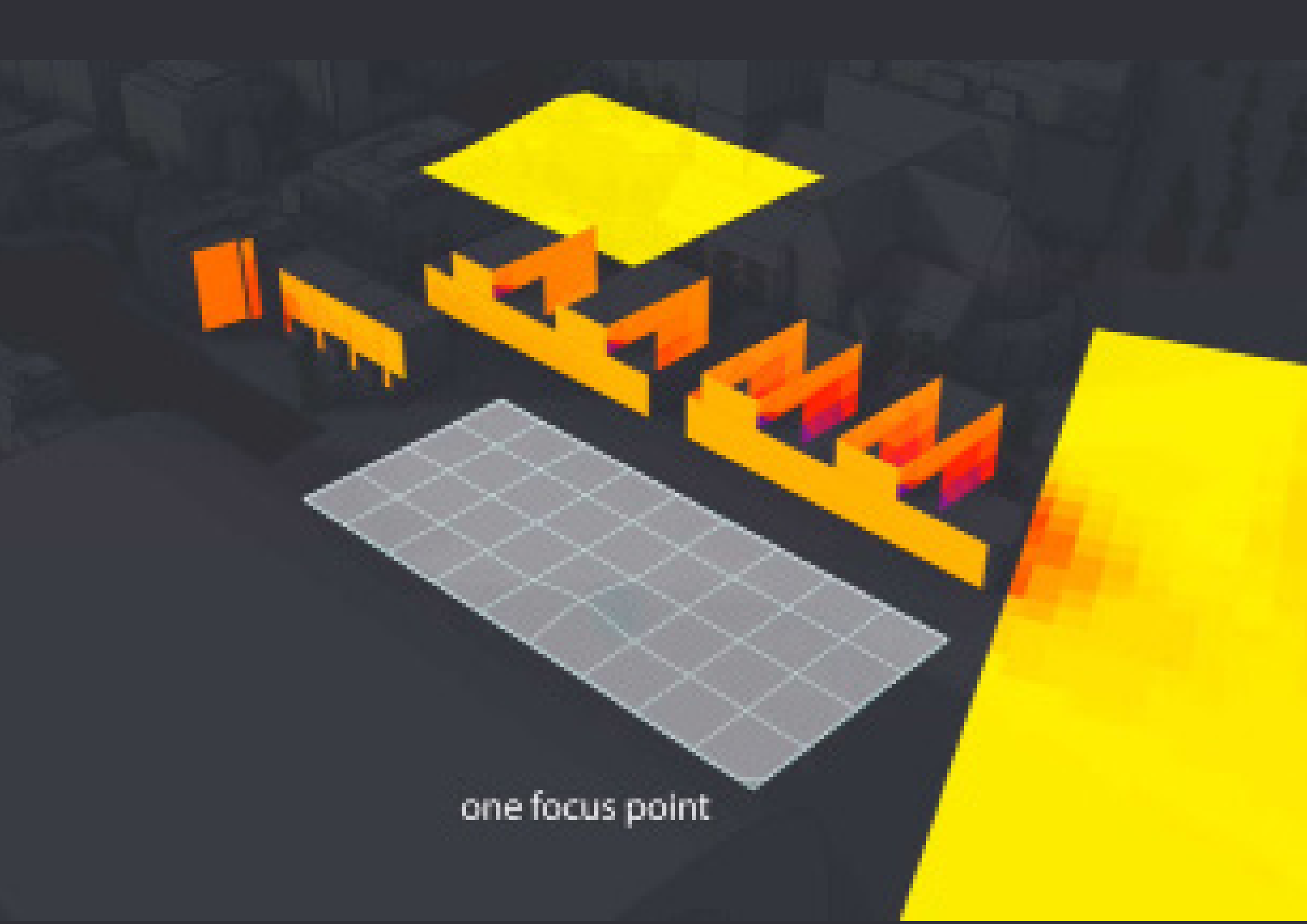
church square
0.00 hrs. reduction/day

neighbouring buildings
< 2.00 hrs. reduction/day

market square
< 1.00 hrs. reduction/day

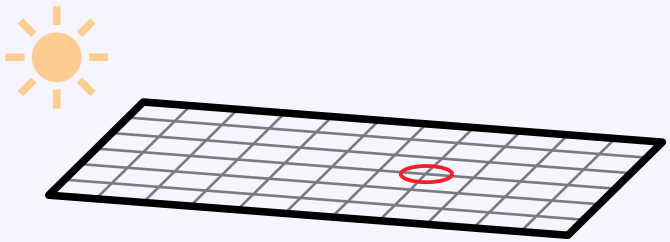
computational logic

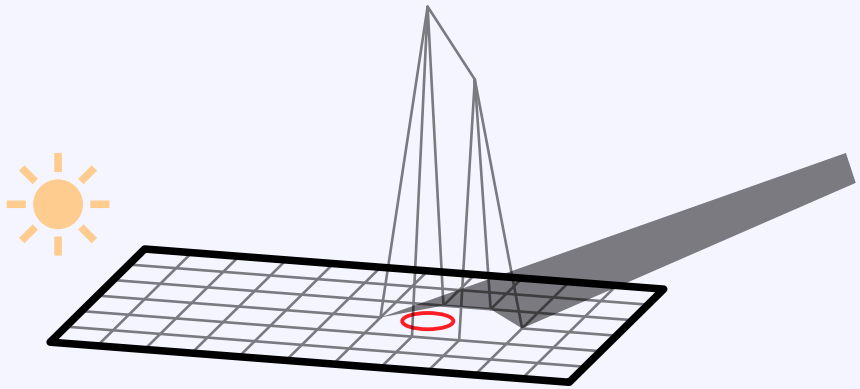



one focus point

pick points

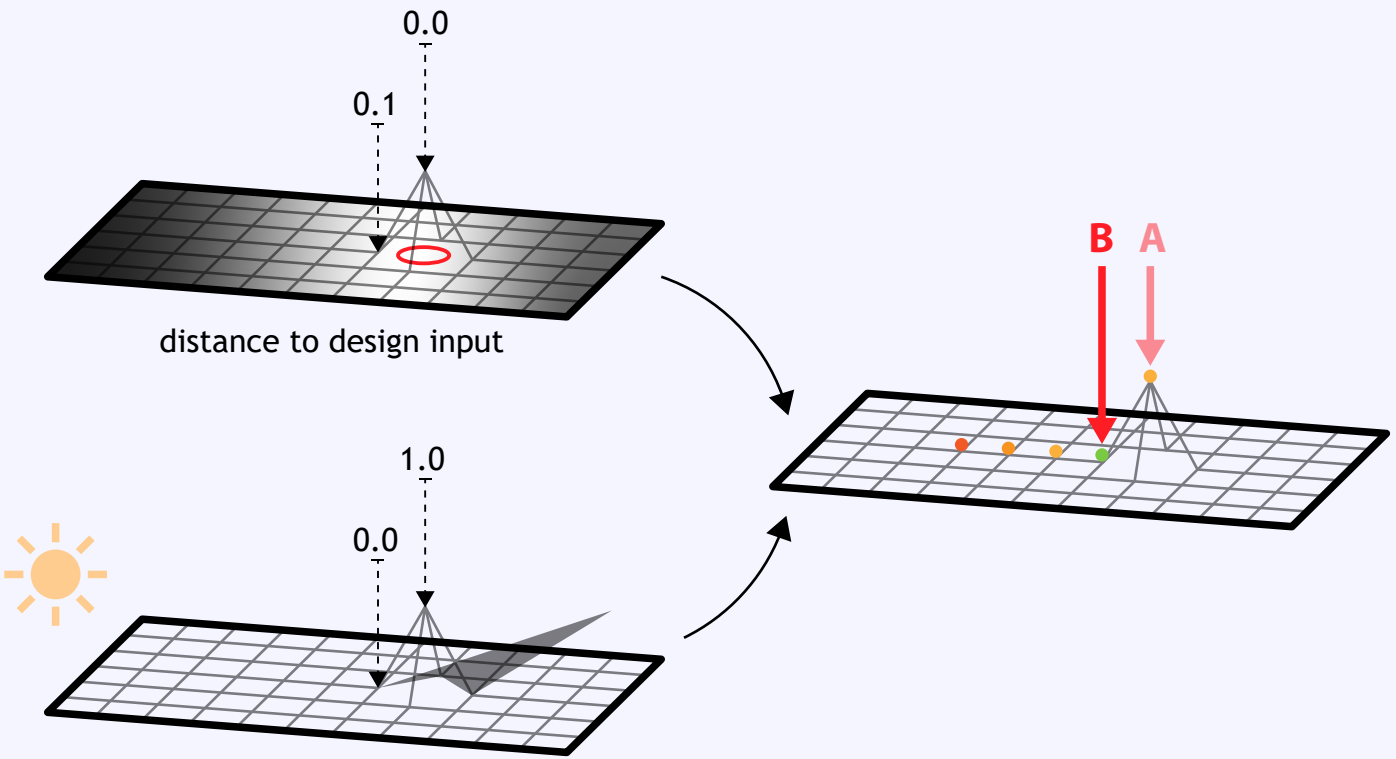
based on design input





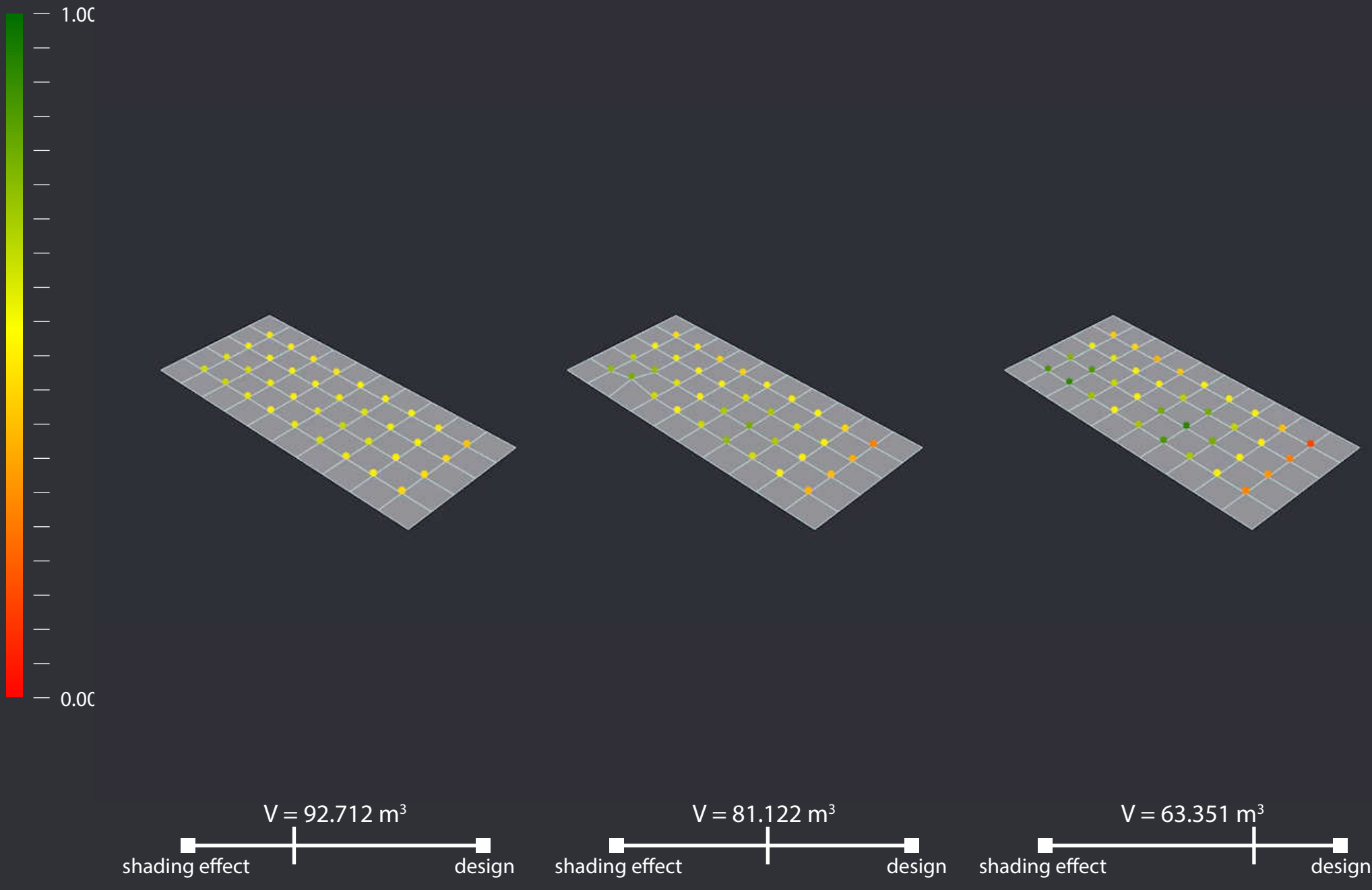
pick points

trade-off between design input and added shading hours



ratio options

varying weight of shading effect vs. design input

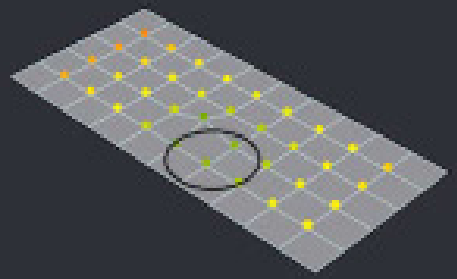


design options

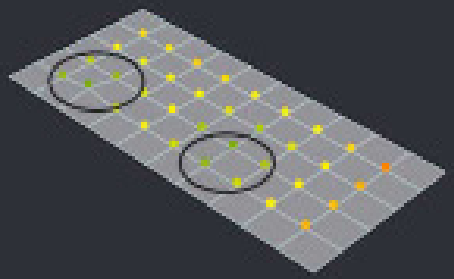
varying design input



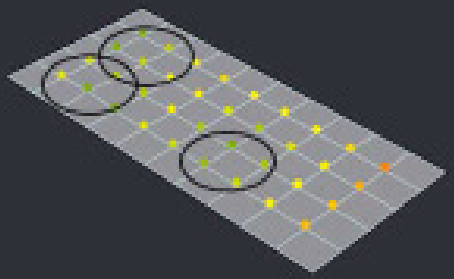
one tower



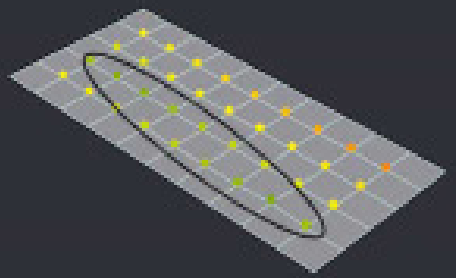
two towers



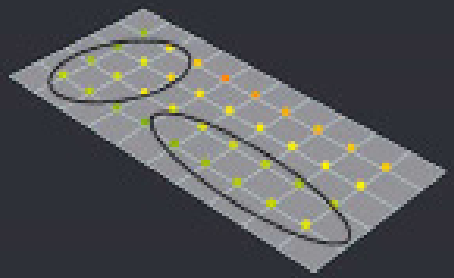
three towers



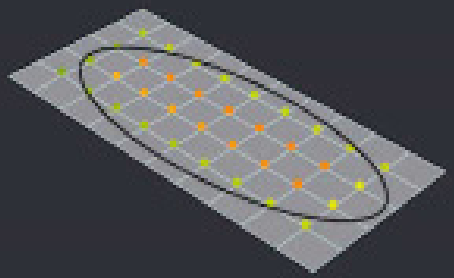
one slab



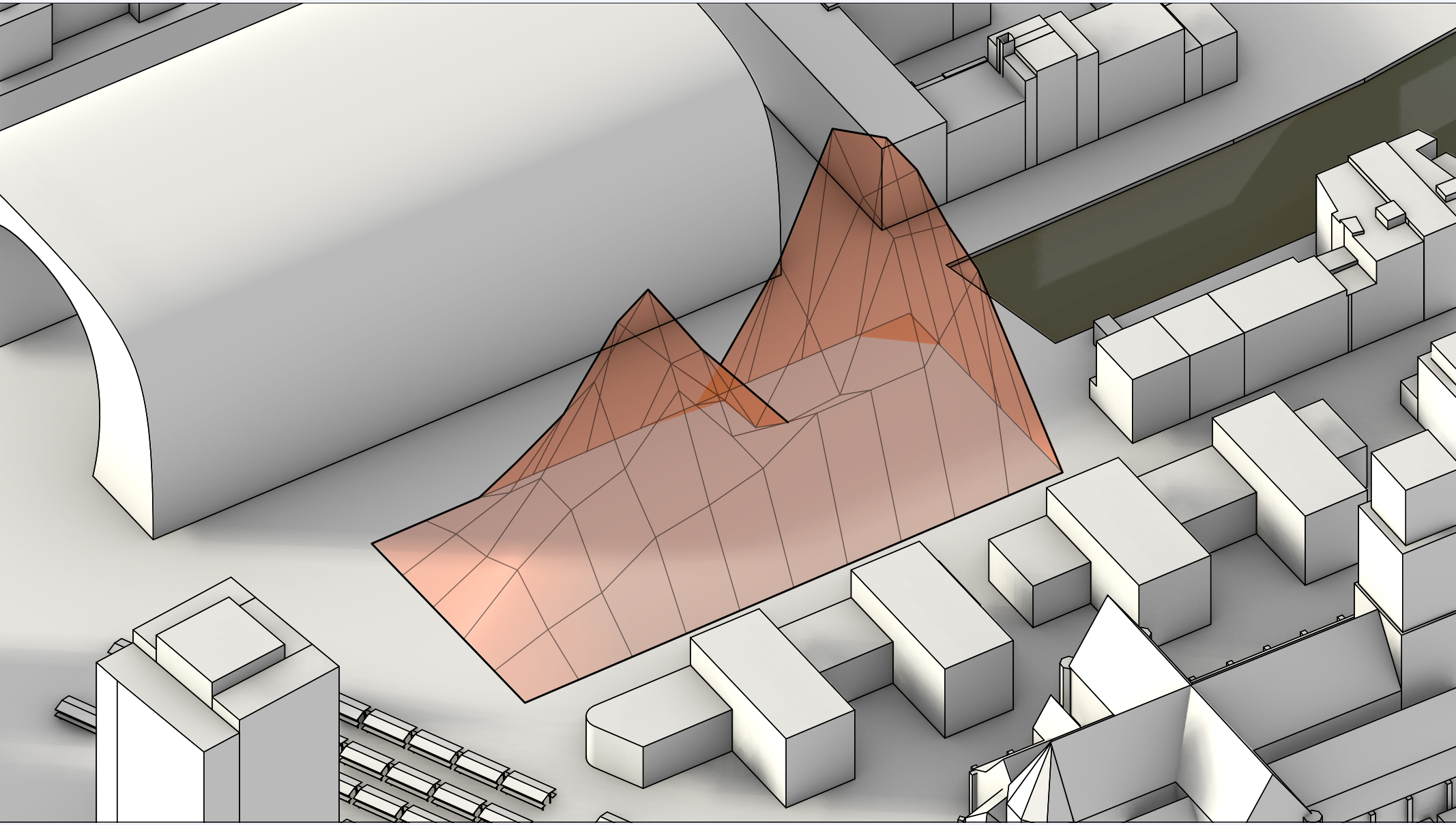
two slabs



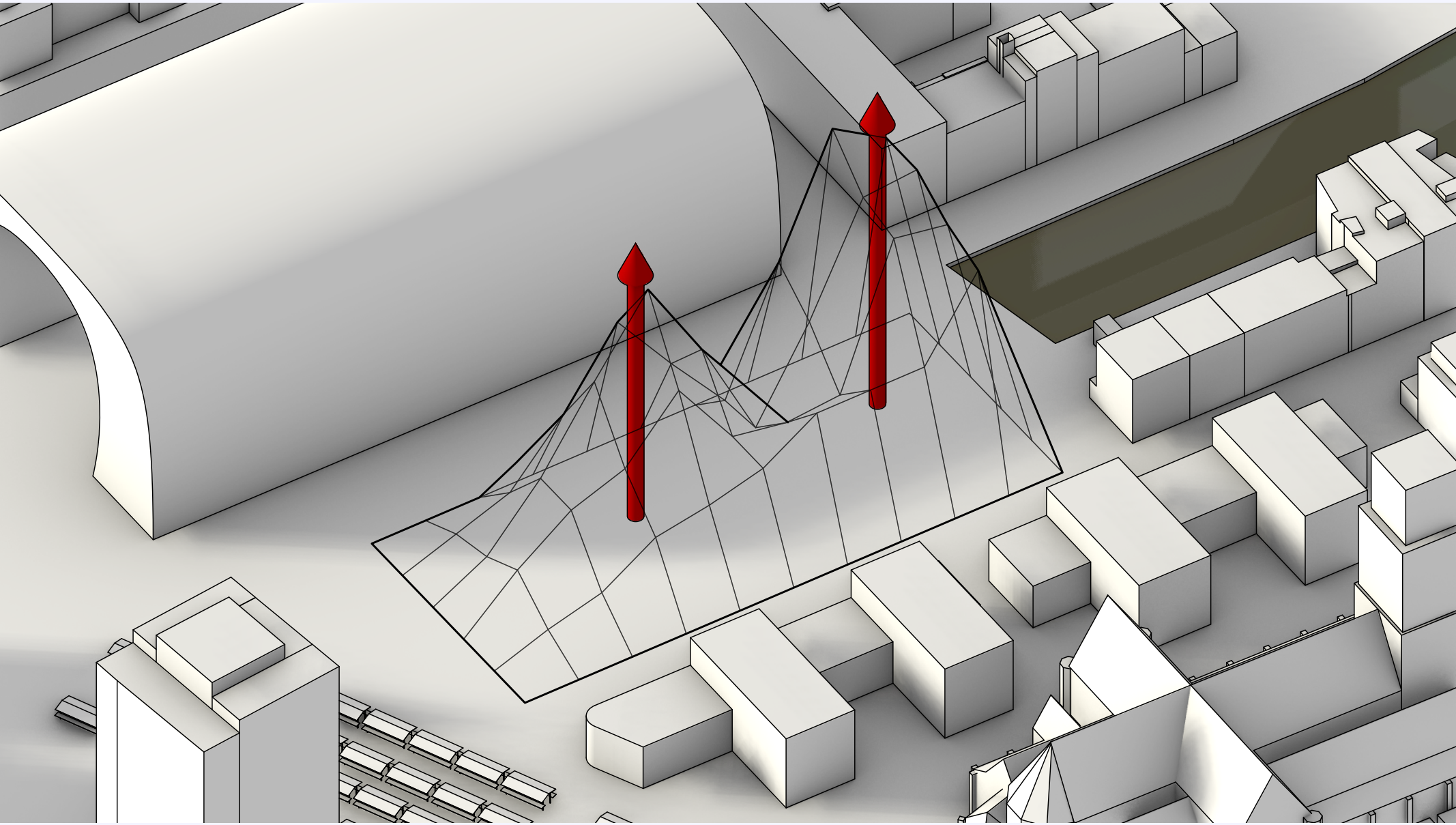
ring



building organization
bounding volume

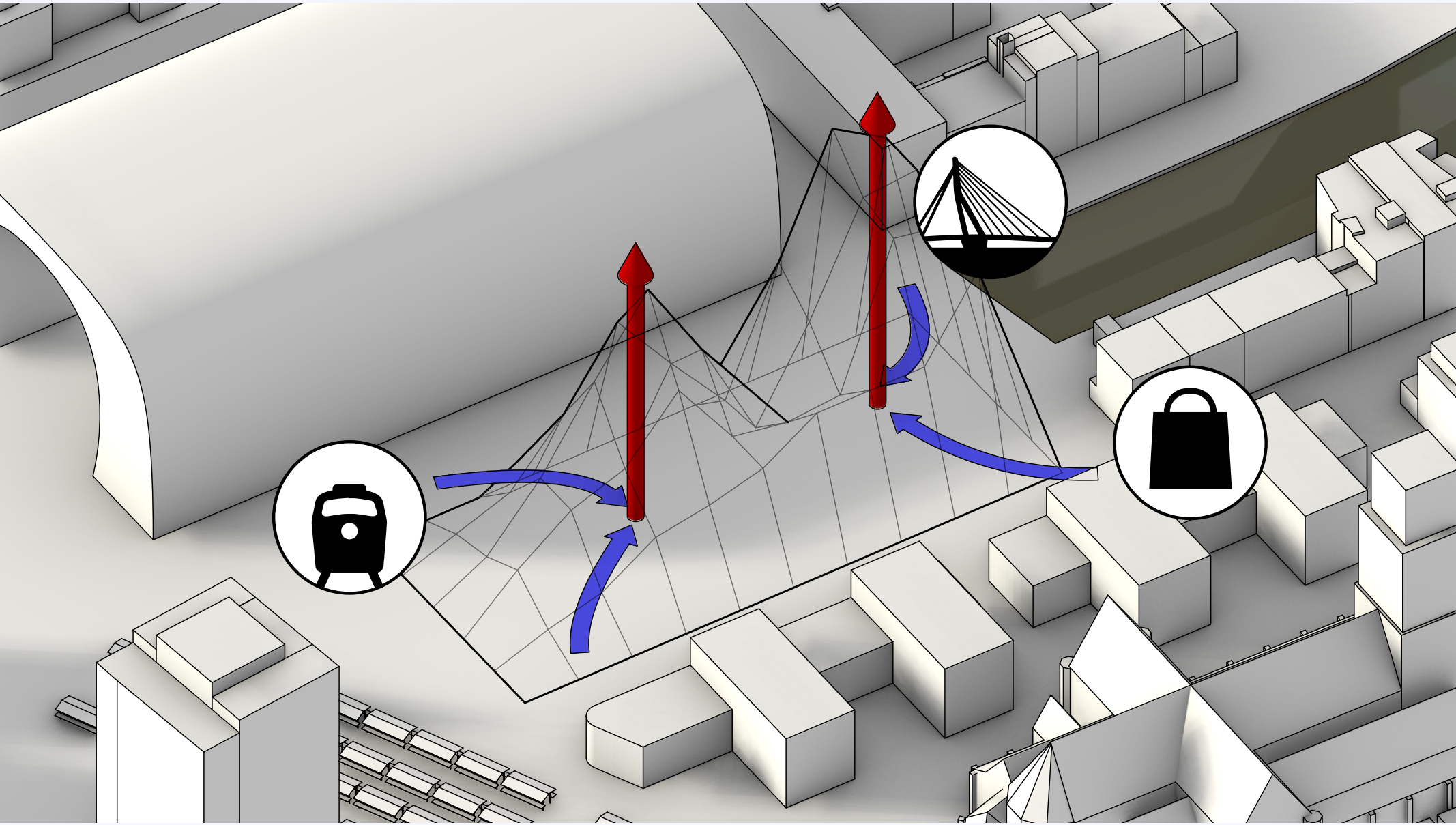


building organization
vertical circulation



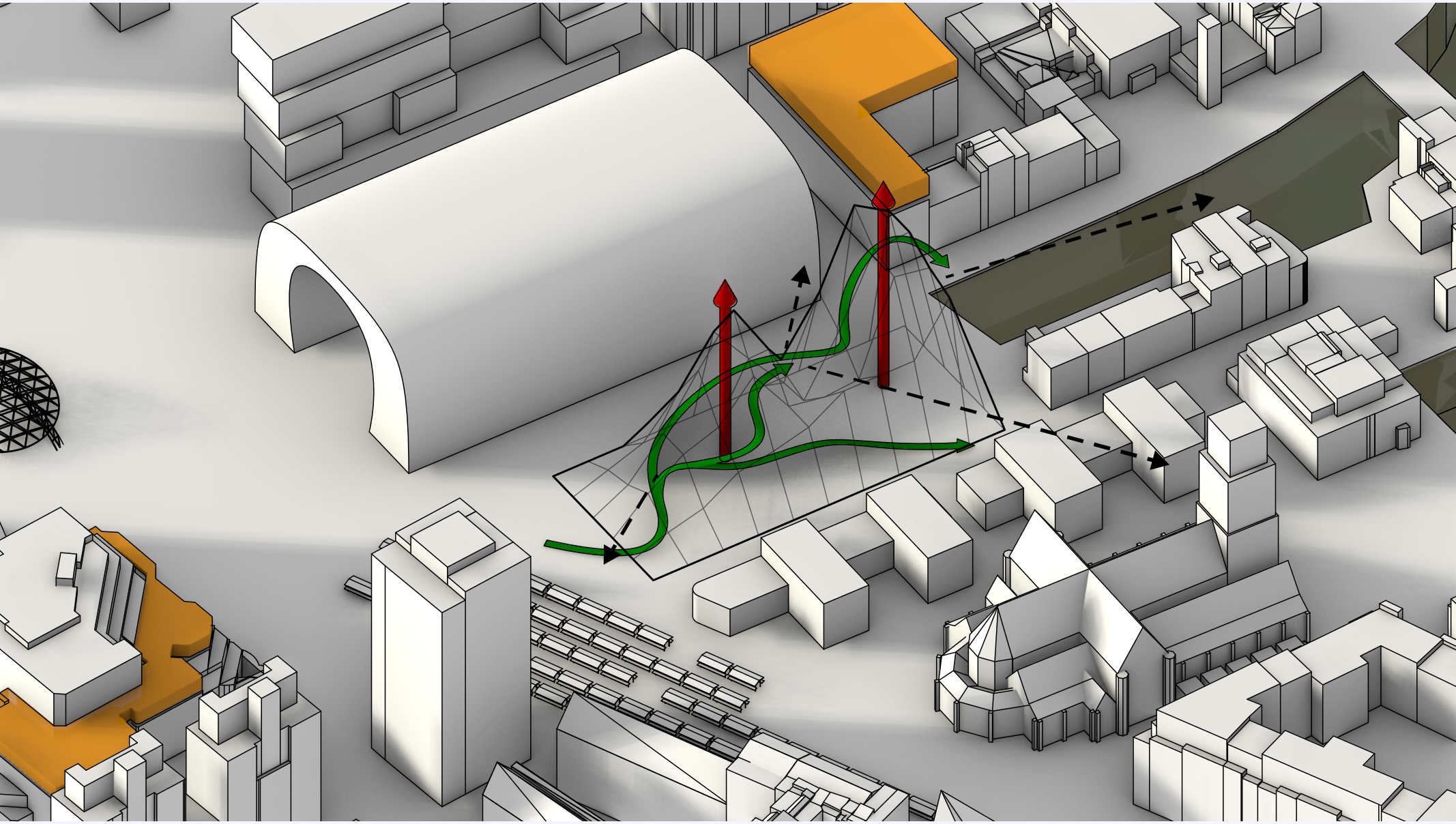
building organization

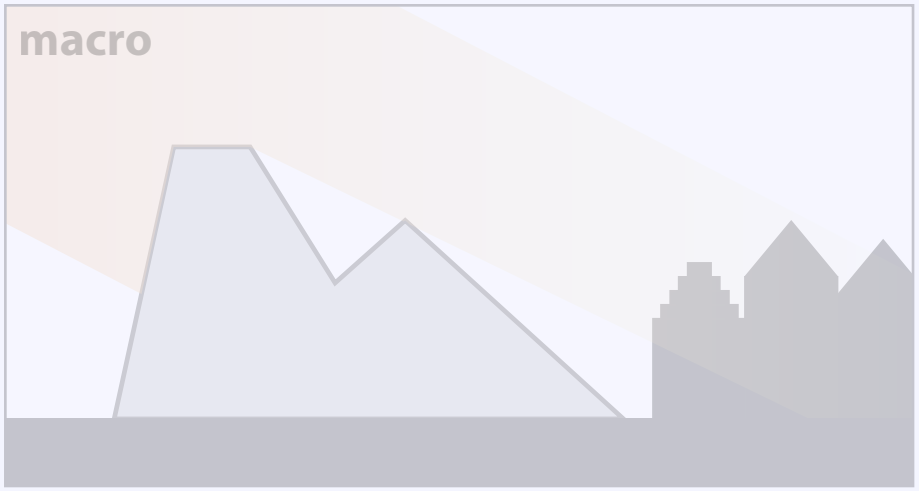
building access



building organization

public path along slopes





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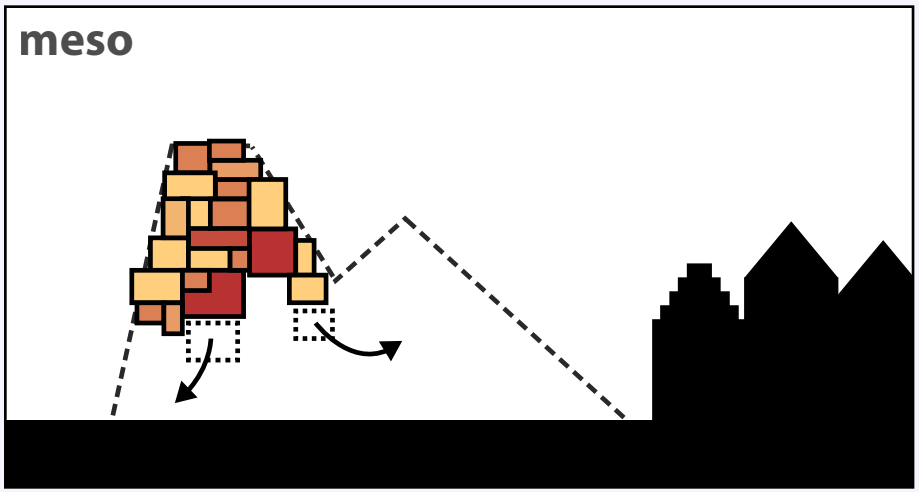
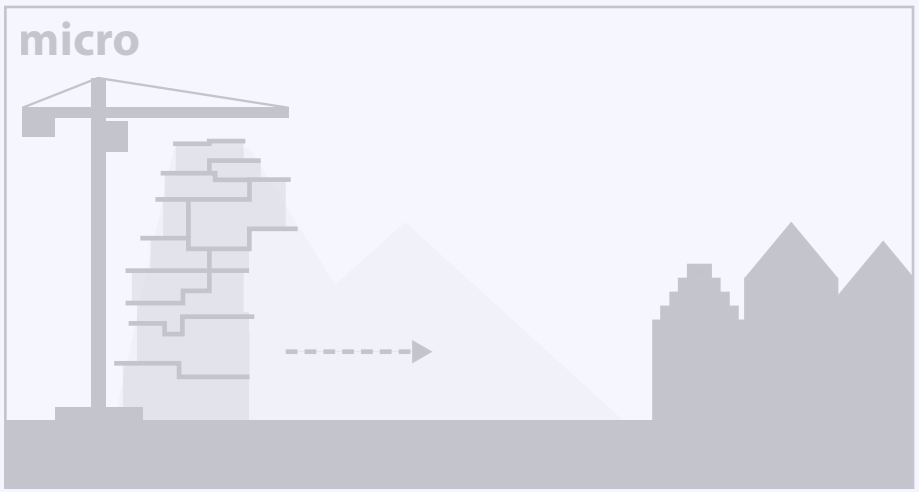


Generative spatial organization with differently sized apartment spaces.

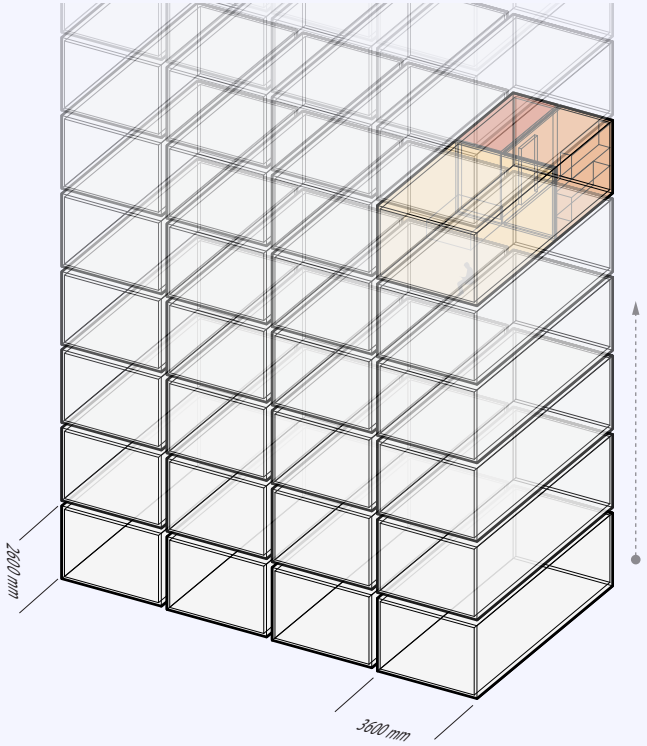


Mass-customizible structural system.

design strategy

top-down

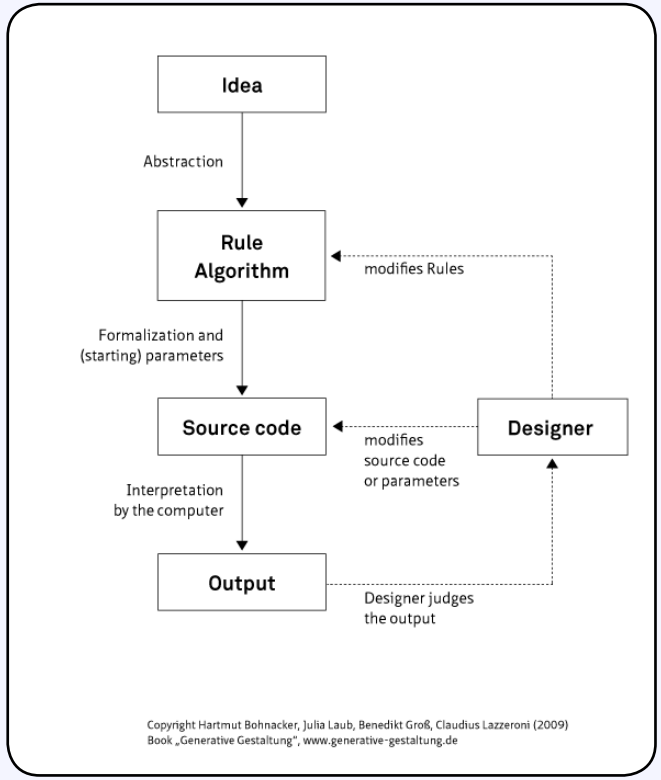
designing a repeatable system



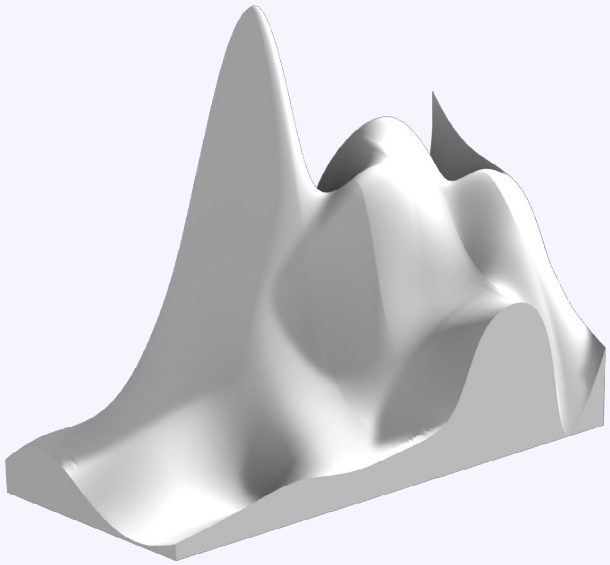
vs.

generative

designing rules which generative algorithm should follow

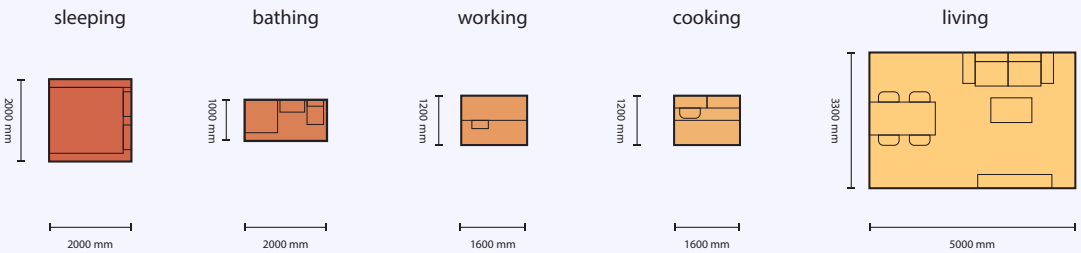


irregular bounding volume

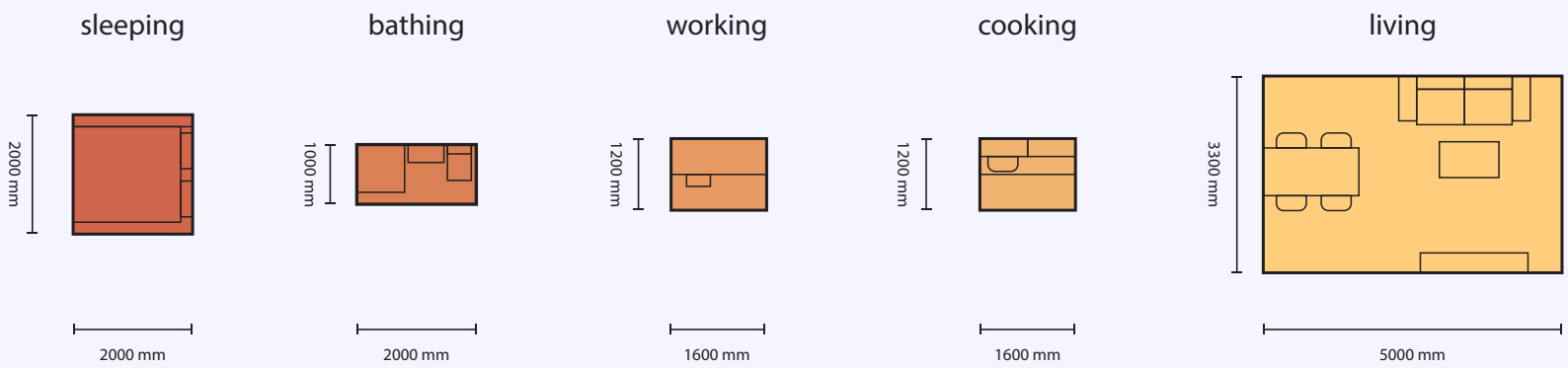


+

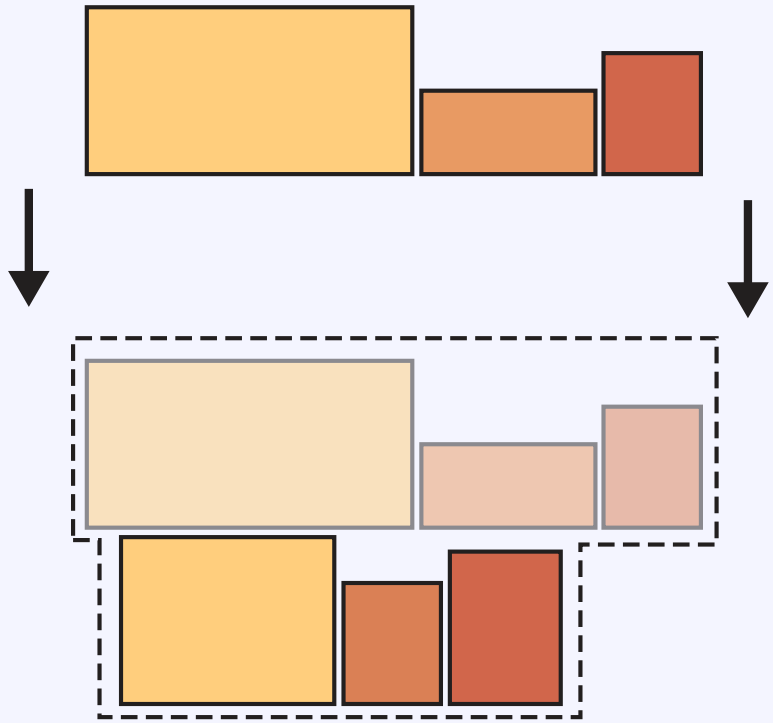
differently sized spaces

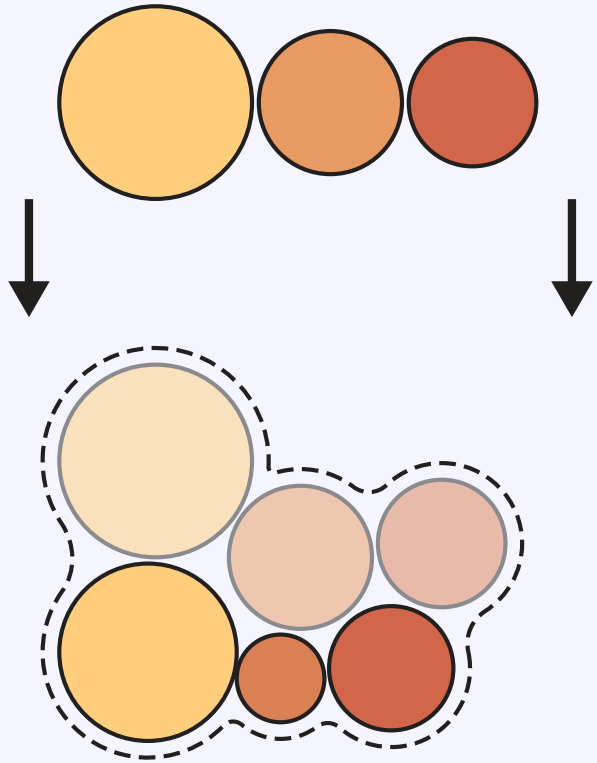


orthogonal functions



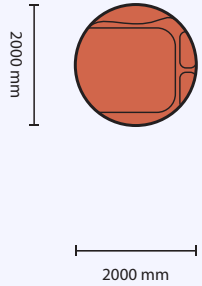
functional packing

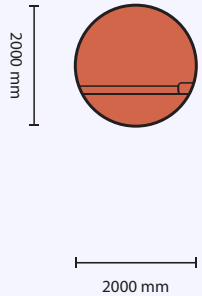




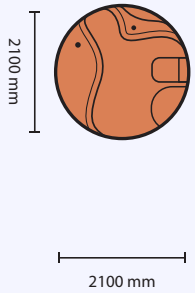
spherical functions

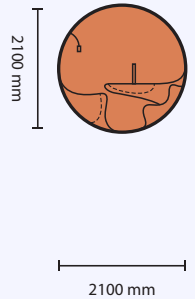
sleeping



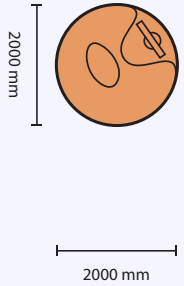


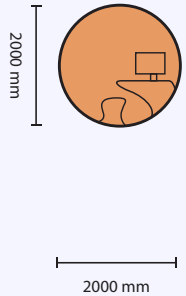
bathing



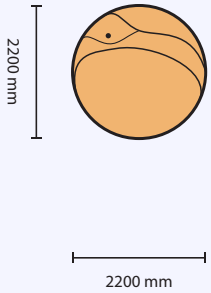


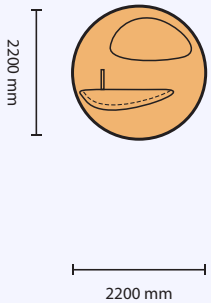
working



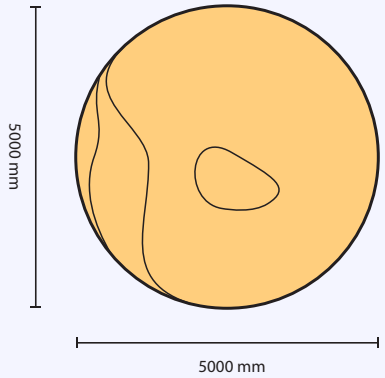


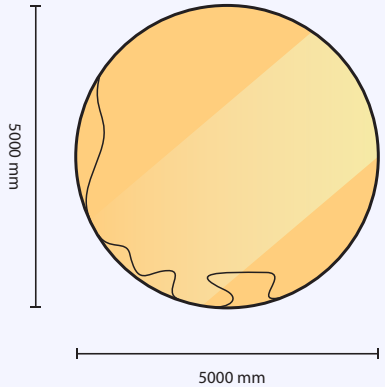
cooking





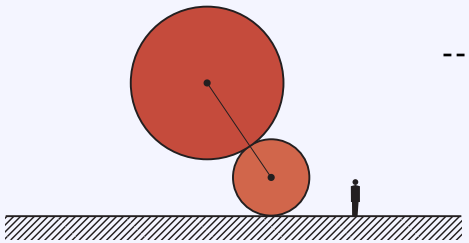
living



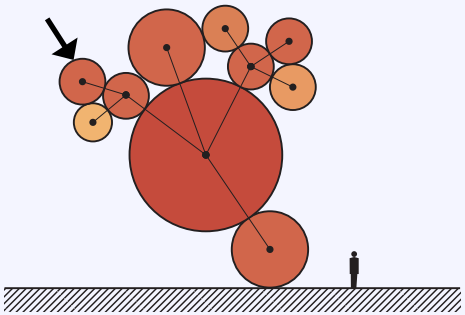


computational growth model
strategy

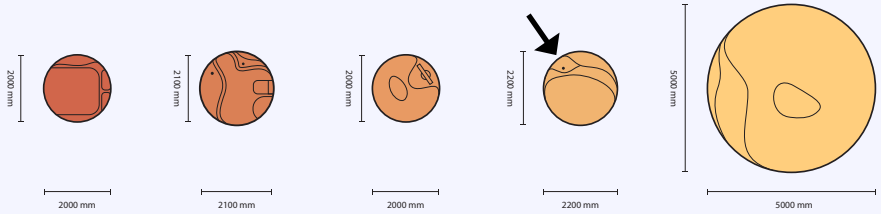
0. design input



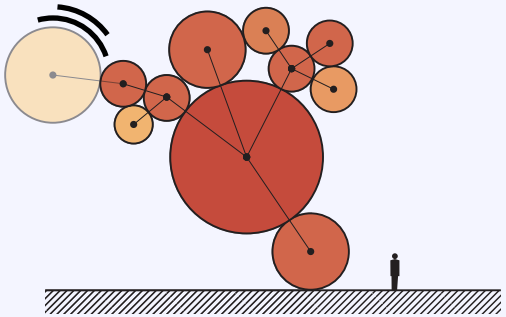
1. pick space to grow from



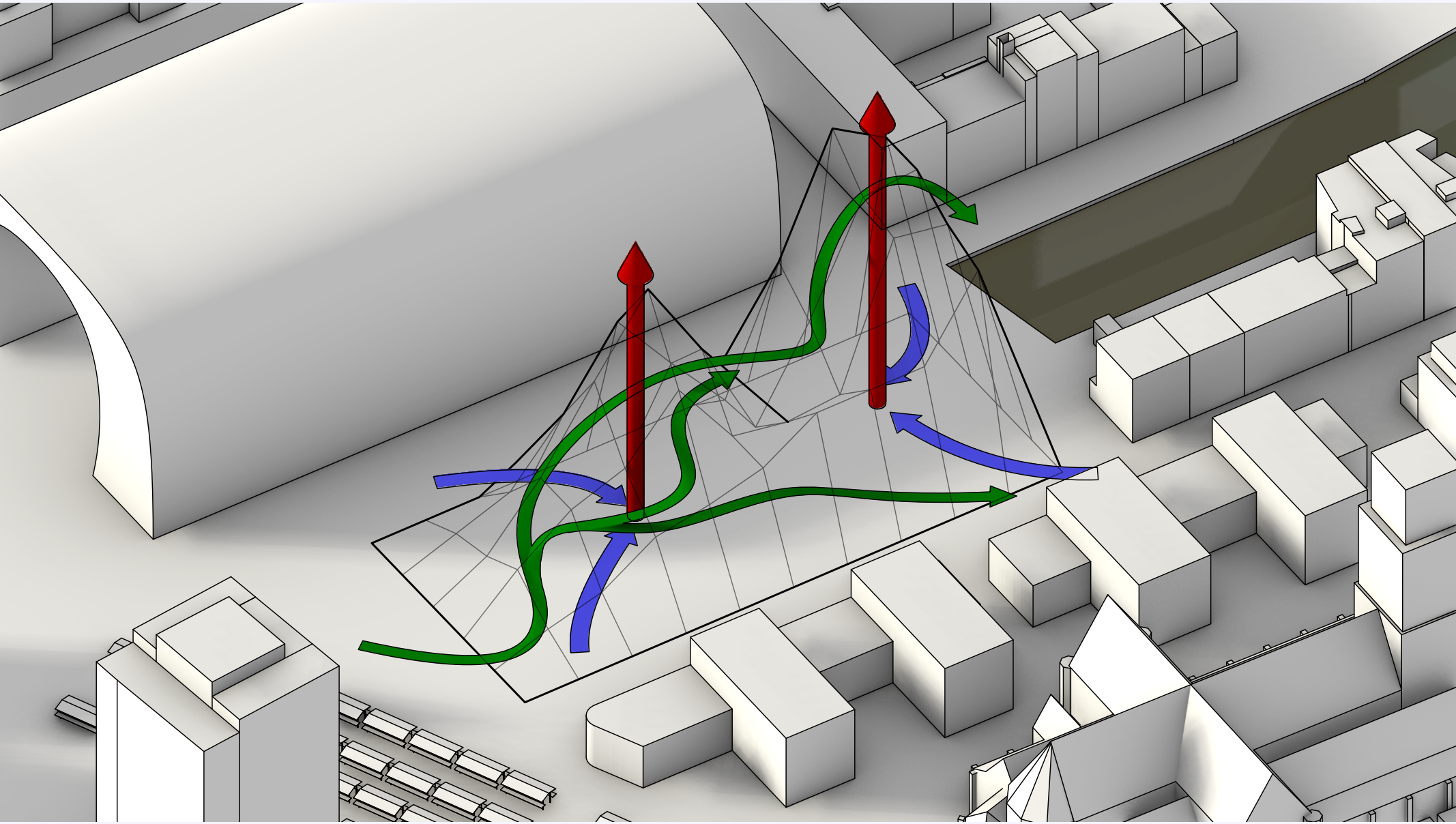
2. pick new category to be added

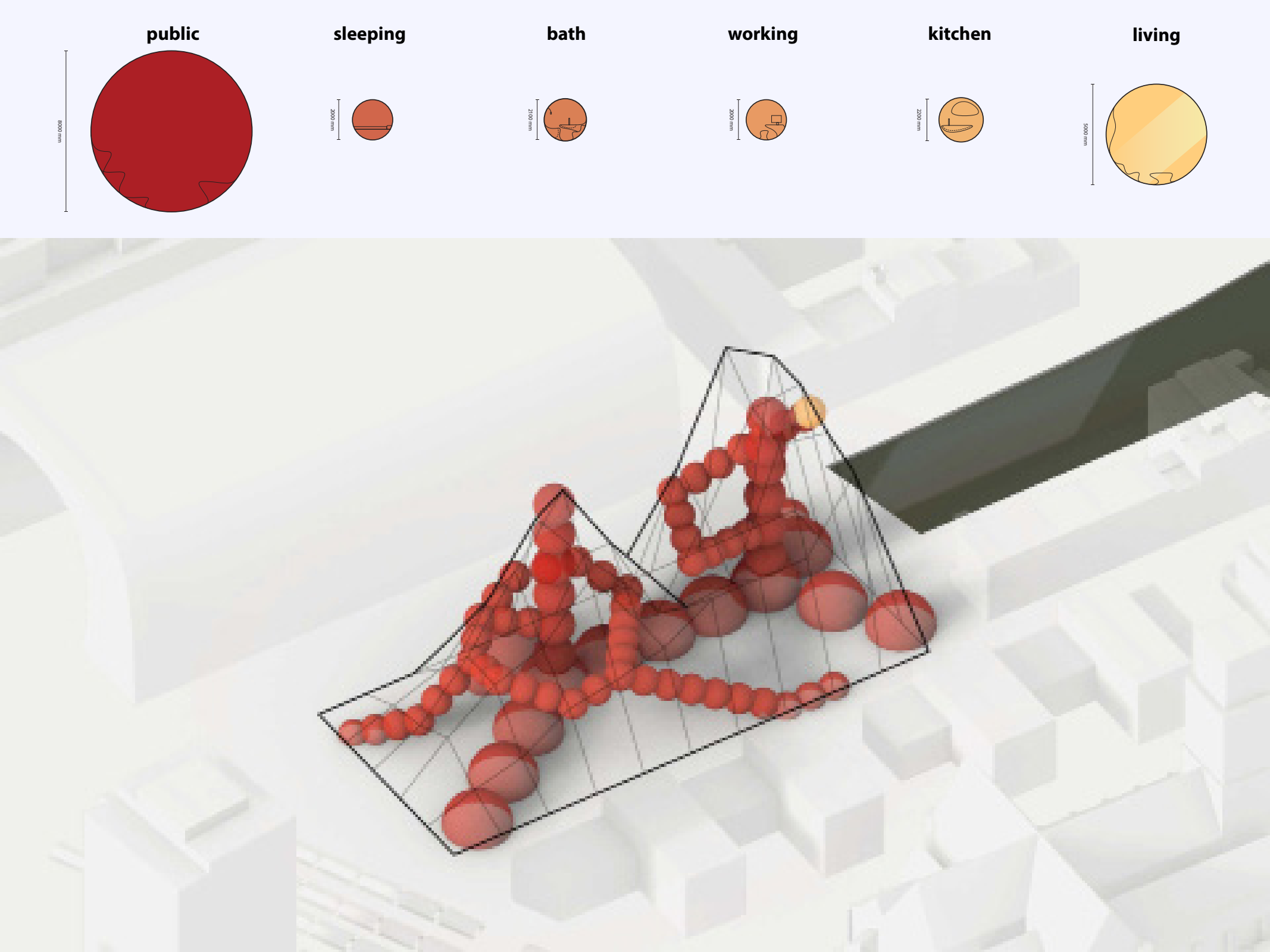


3. physical simulation

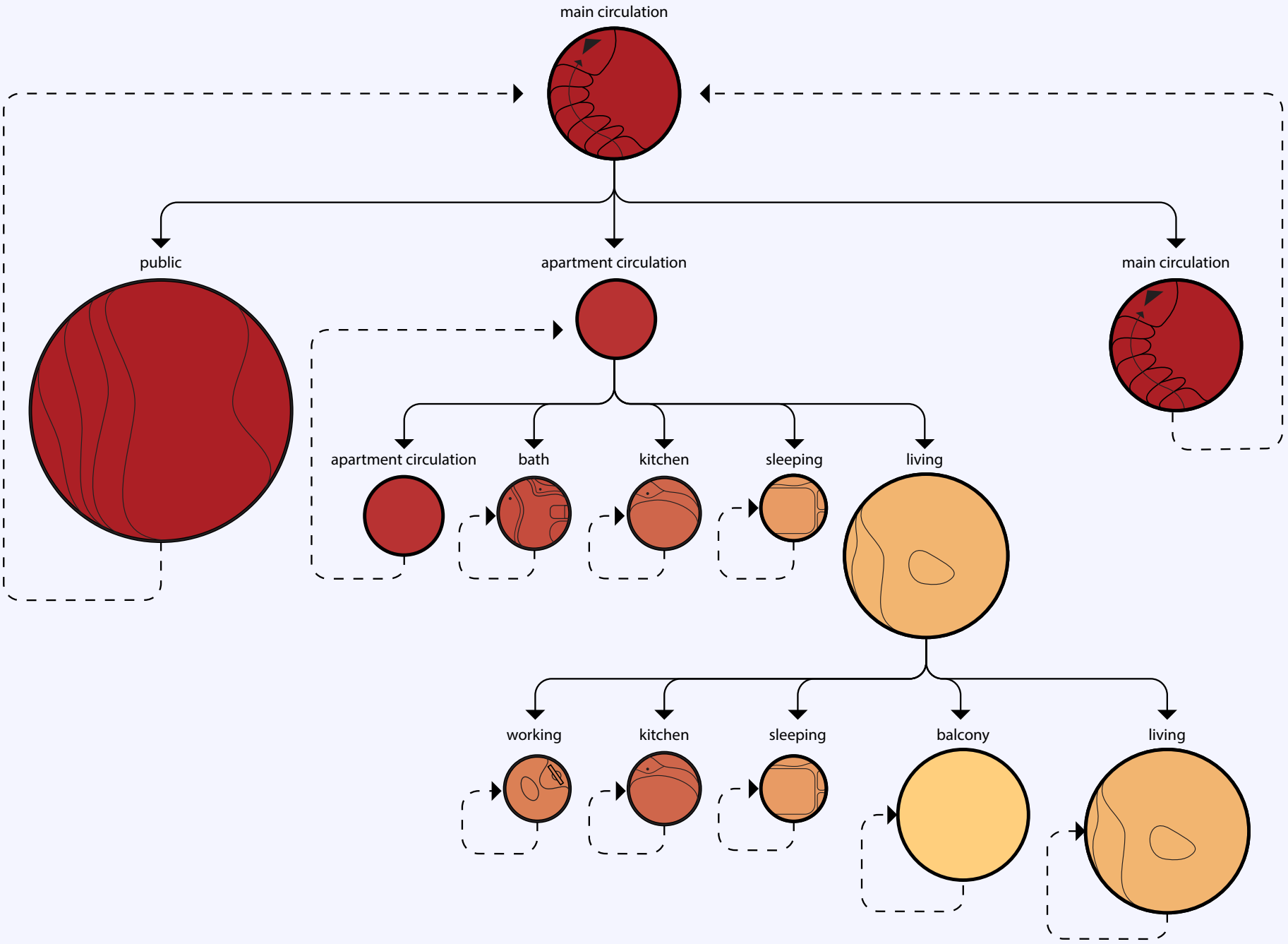


design input



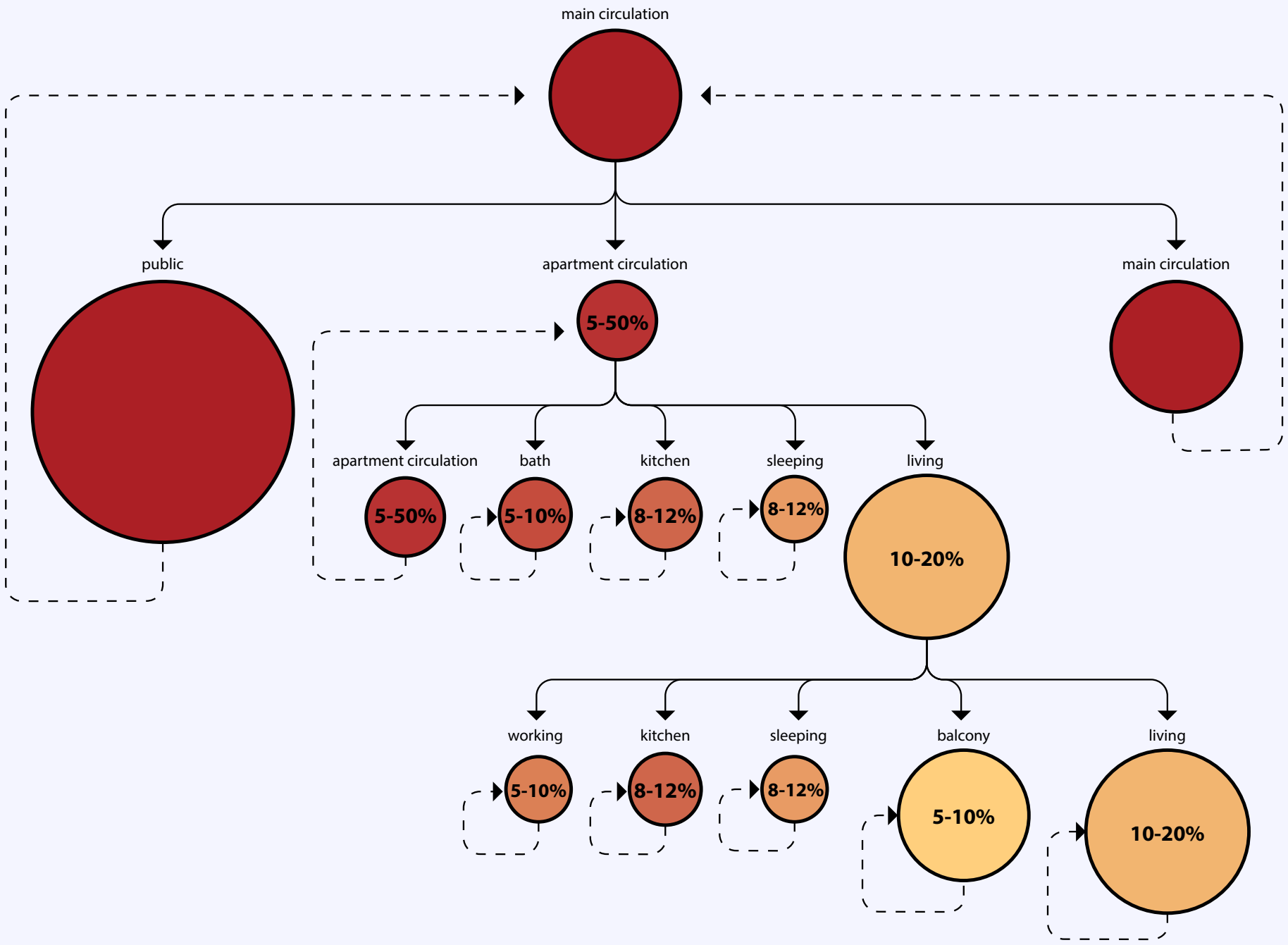

public
8000 mm
sleeping
2000 mm
bath
2100 mm
working
2000 mm
kitchen
2200 mm
living
5000 mm

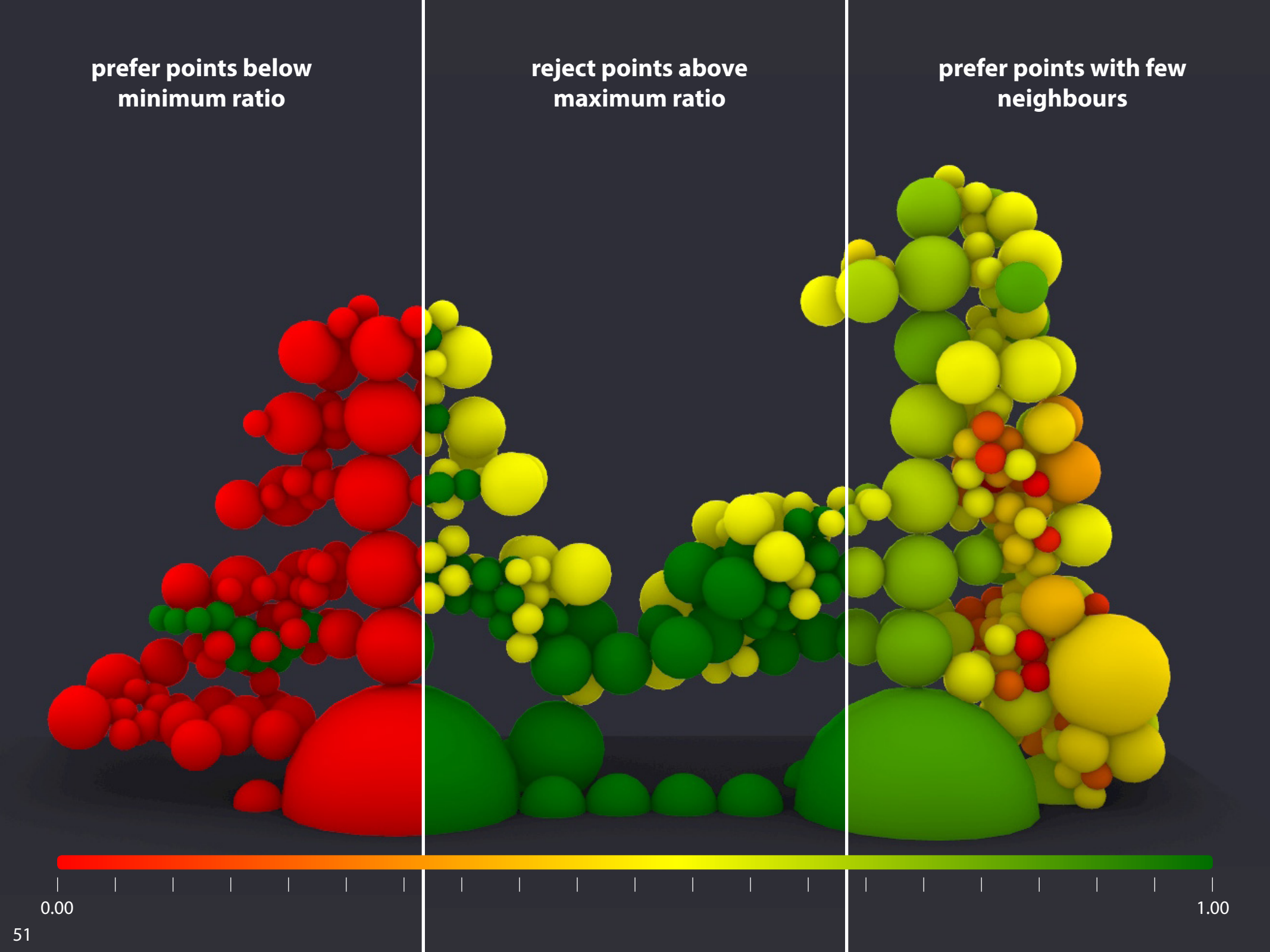
functional flowchart



functional flowchart

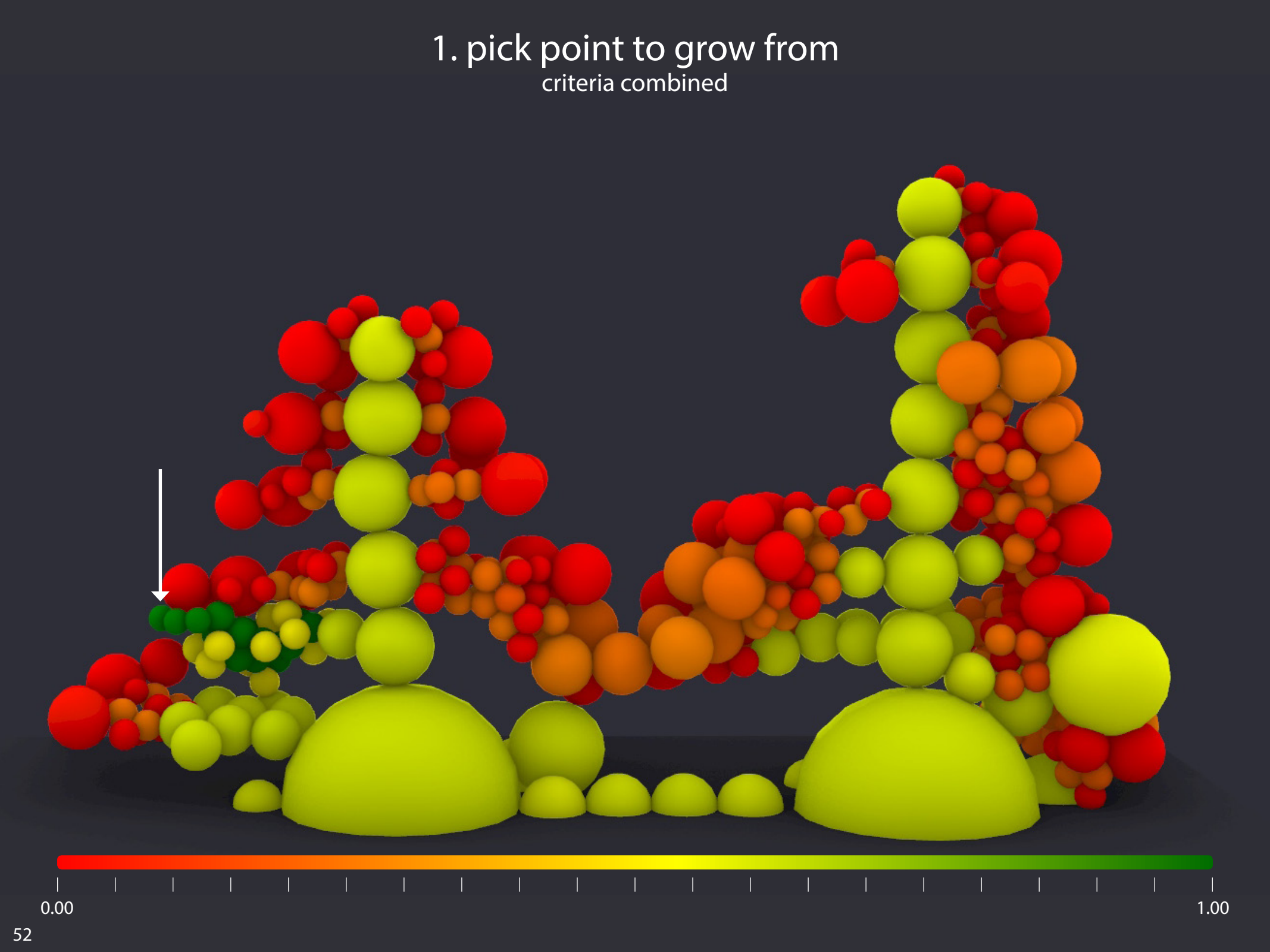
ideal ratios



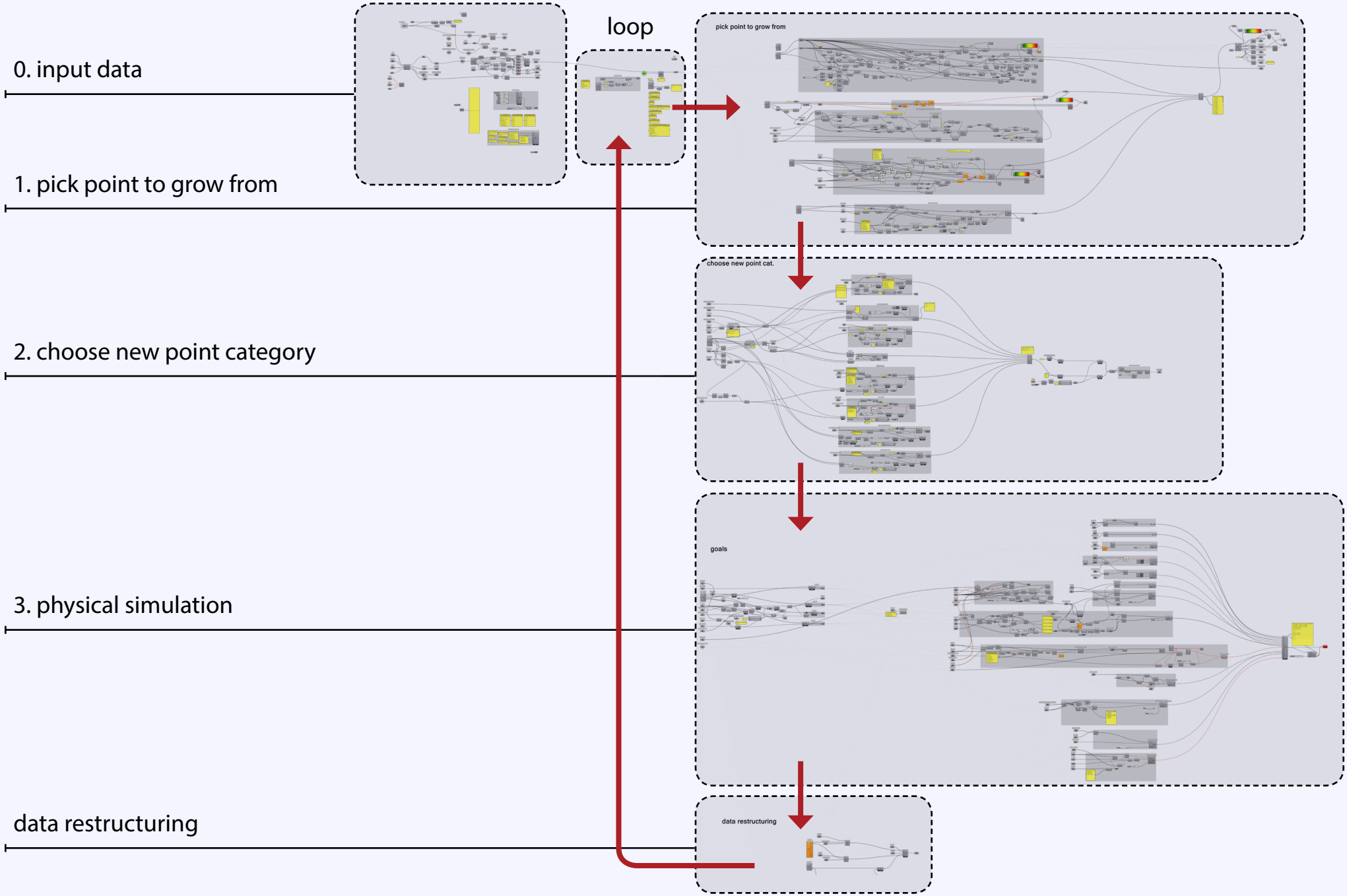

prefer points below minimum ratio
reject points above maximum ratio
prefer points with few neighbours
0.00
1.00

1. pick point to grow from

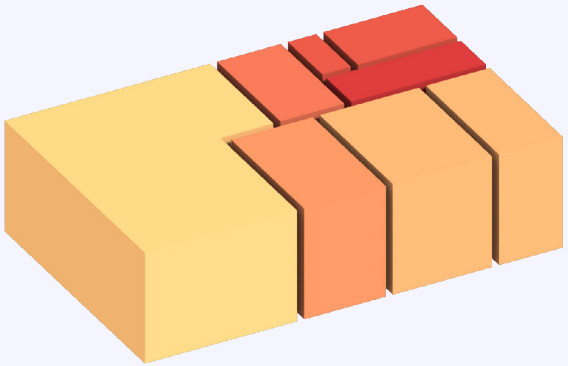
criteria combined



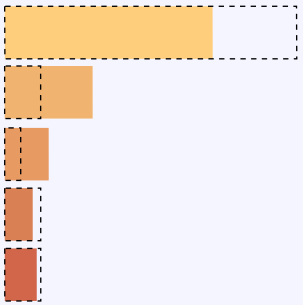
behind the scenes



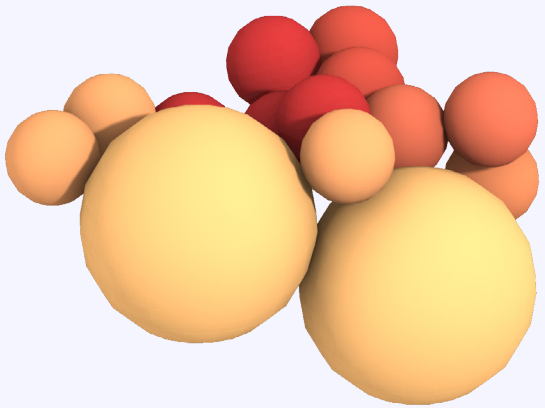
generative design result
functional division comparison



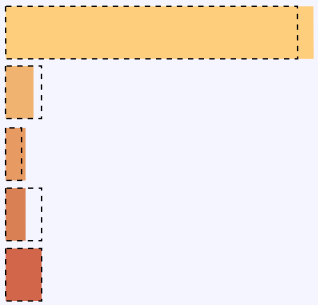
Standard living unit - 256 m³



52% living rooms + kitchen
22% bedrooms
11% study
8% bathrooms
6% others

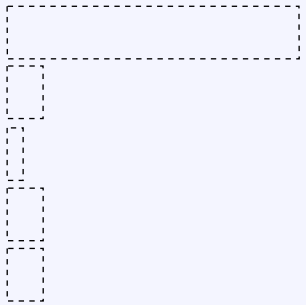


Living unit from generative model - 301 m³



77% living rooms + kitchen
7% bedrooms
5% study
5% bathrooms
9% others

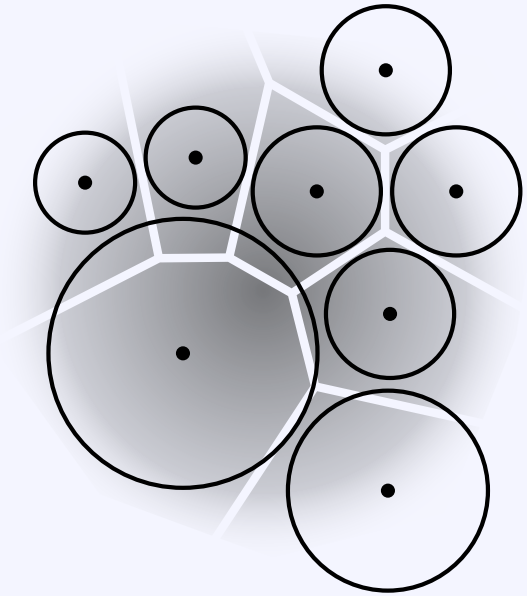
Time spent awake in each room when at home



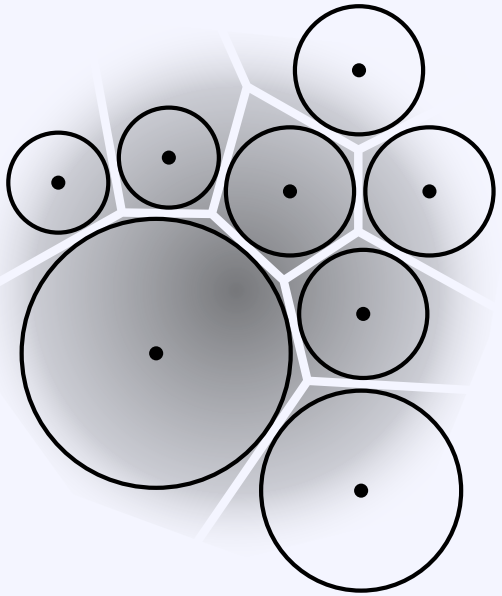
73% living rooms + kitchen
9% bedrooms
4% study
9% bathrooms
4% others

Considering 08:00 hours of sleep per day as well as an average of 6:18 hours spent outdoors. Rounded to whole percentages.
Based on: Khajehzadeh, Iman & Vale, Brenda. (2015). How do people use large houses?.

weighted voronoi

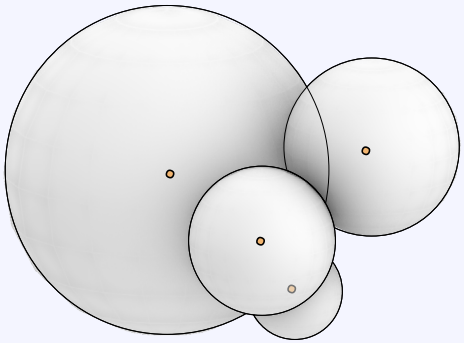


voronoi diagram

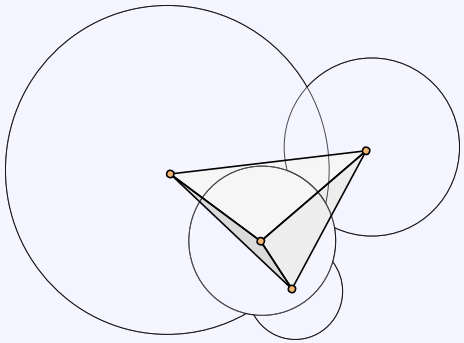


weighted voronoi diagram

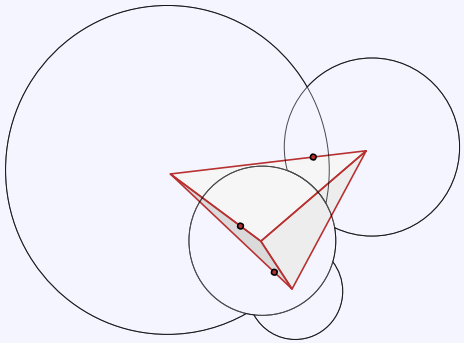
weighted voronoi
step-by-step



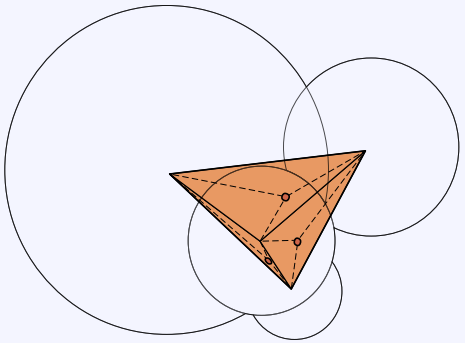
0.
base geometry,
points + radii



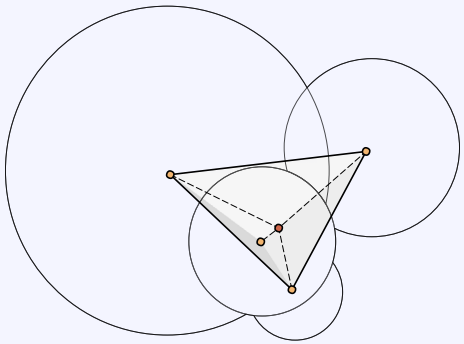
1.
tetrahedralization



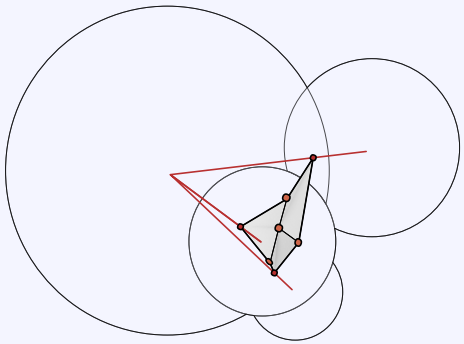
2.
edge weighted
midpoints



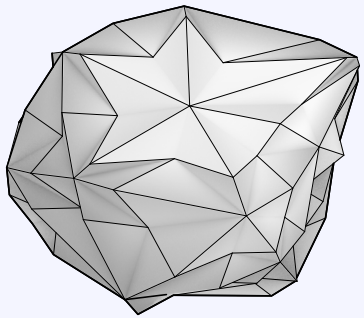
3.
face weighted
midpoints



4.
weighted average of
tetrahedra corners

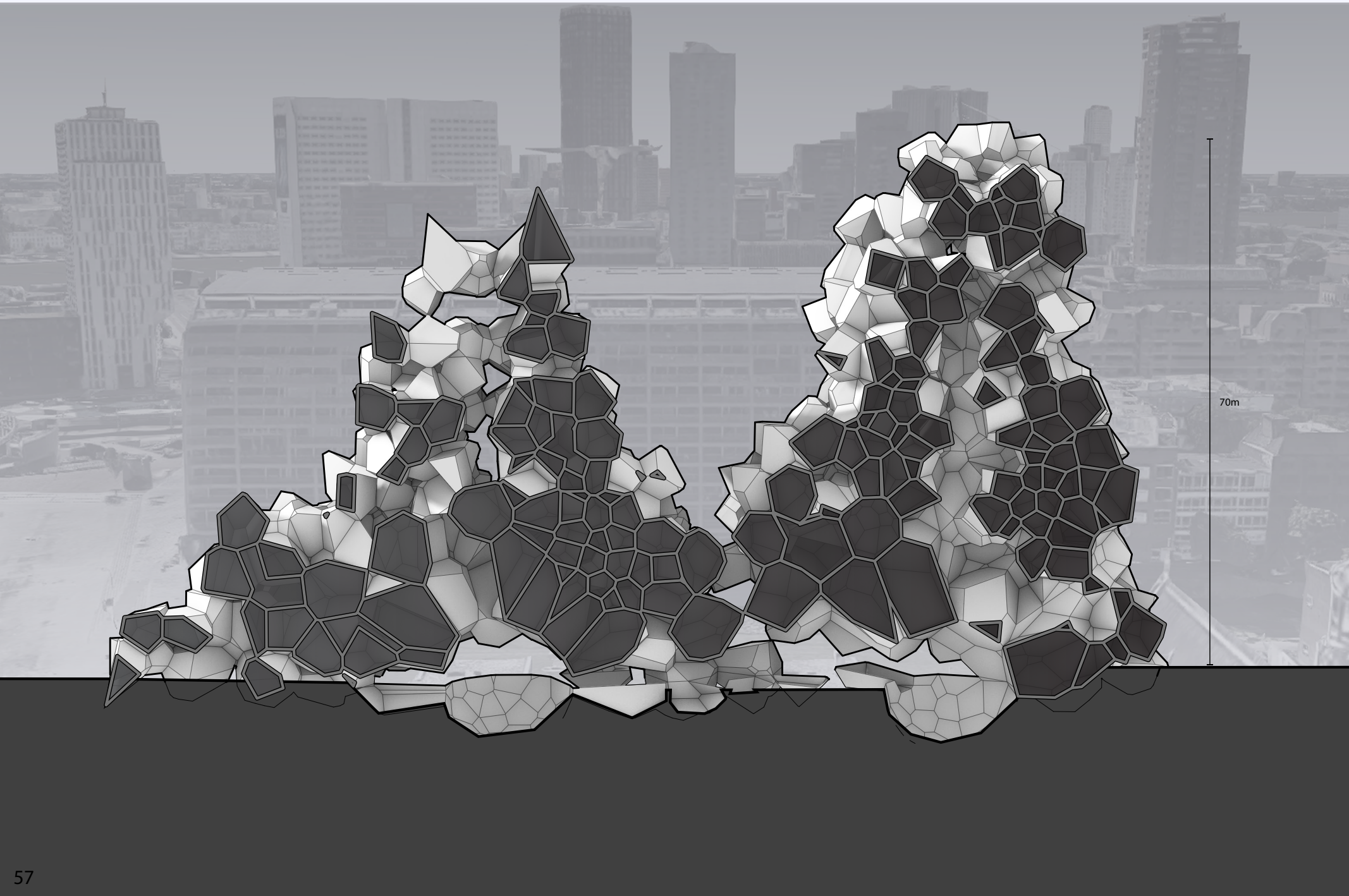


5.
combining points of step
2,3,4 into three 4-vertex
mesh faces

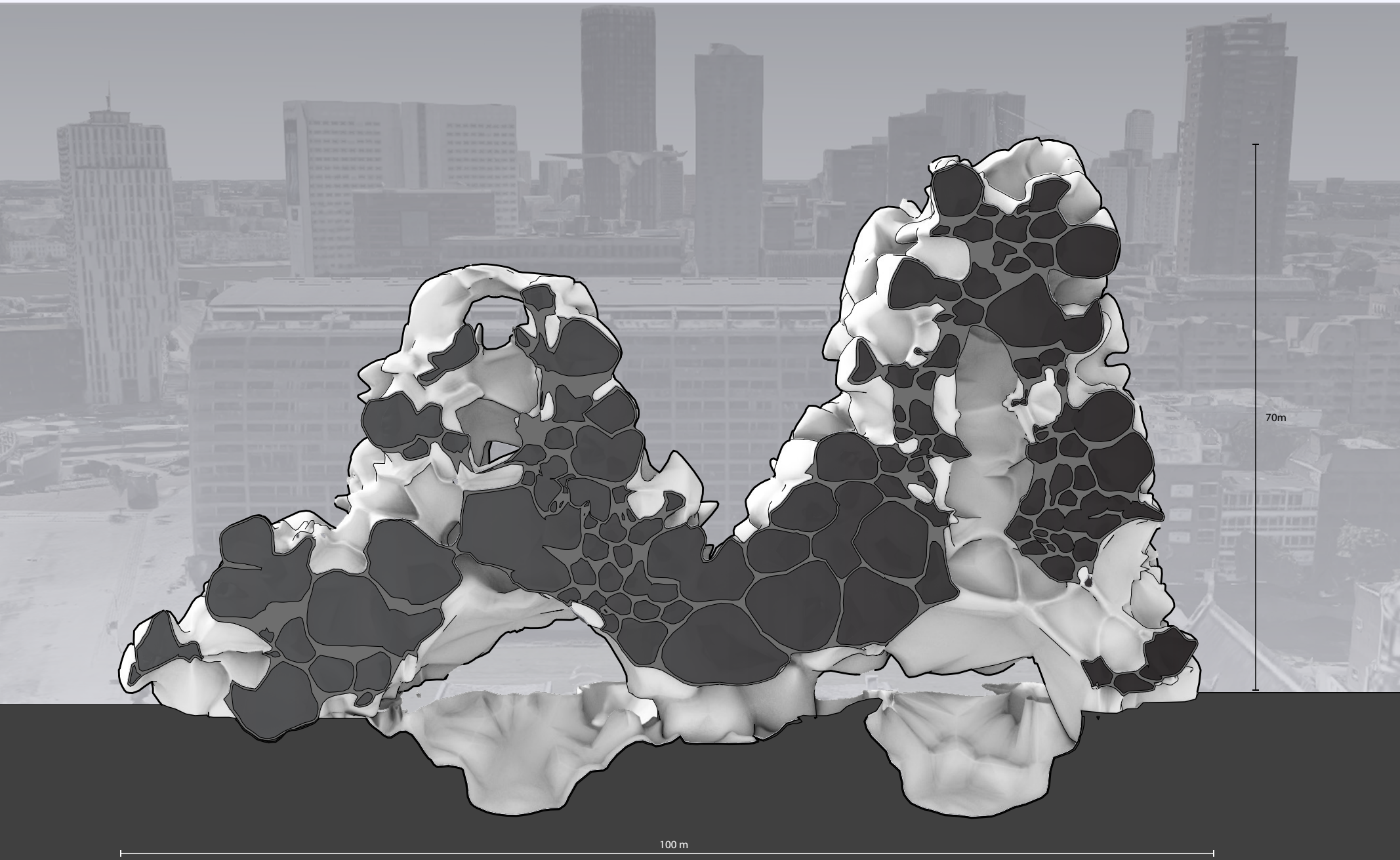


6.
combining faces of each
origin point to complete
mesh

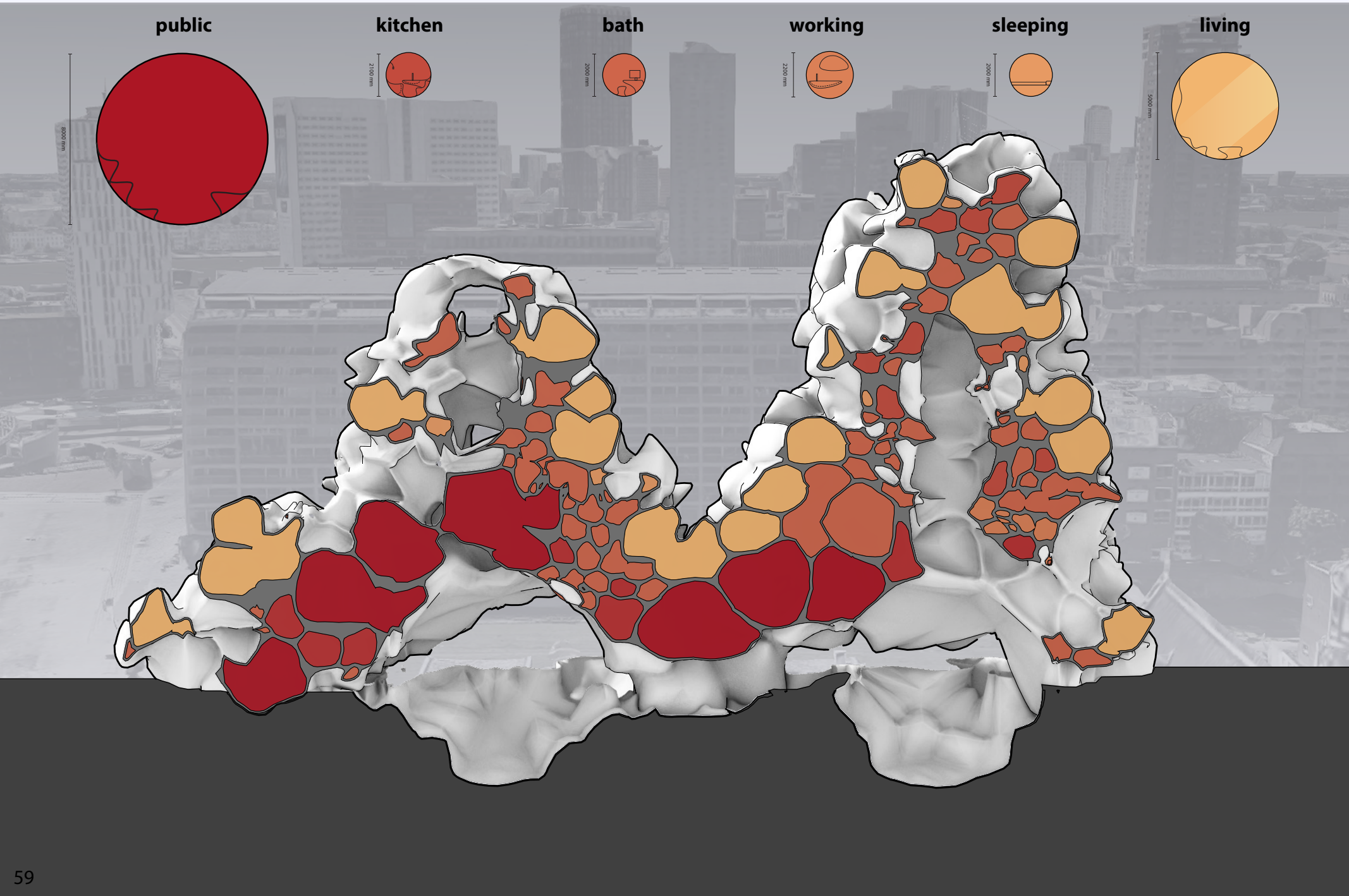
section
faceted



section

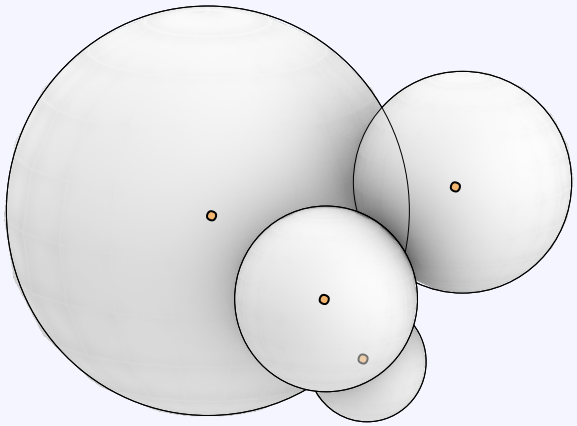


functions

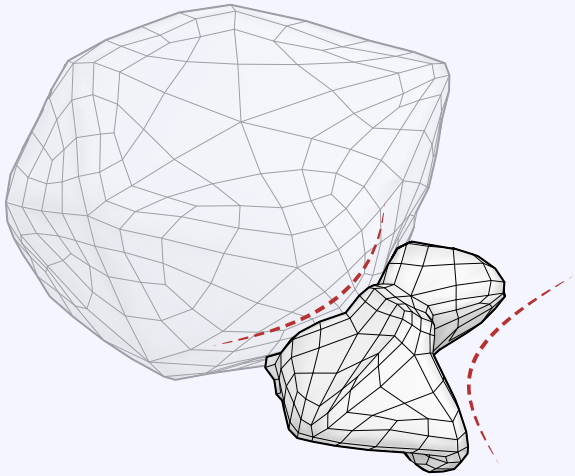

public
kitchen
bath
working
sleeping
living
8000 mm
2100 mm
2000 mm
2200 mm
2000 mm
5000 mm

weighted voronoi

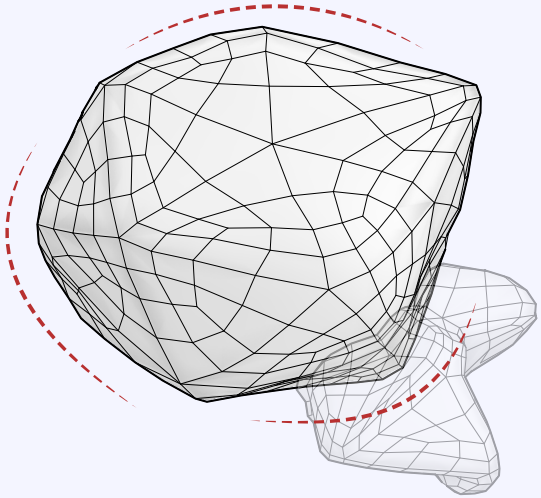
convex vs. concave



Base geometry,
differently sized spheres



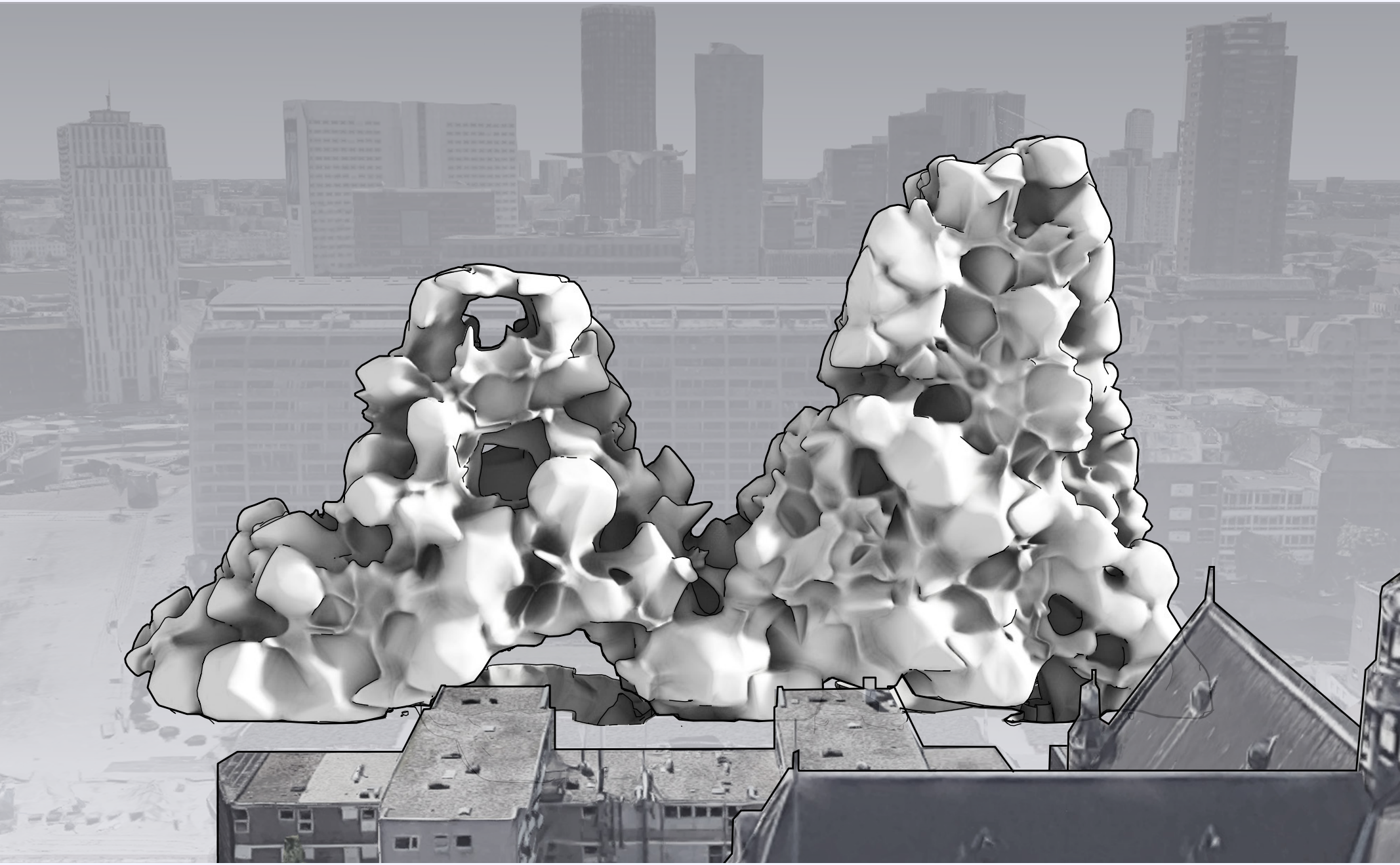
Concave weighted voronoi
mesh [relatively small sphere]



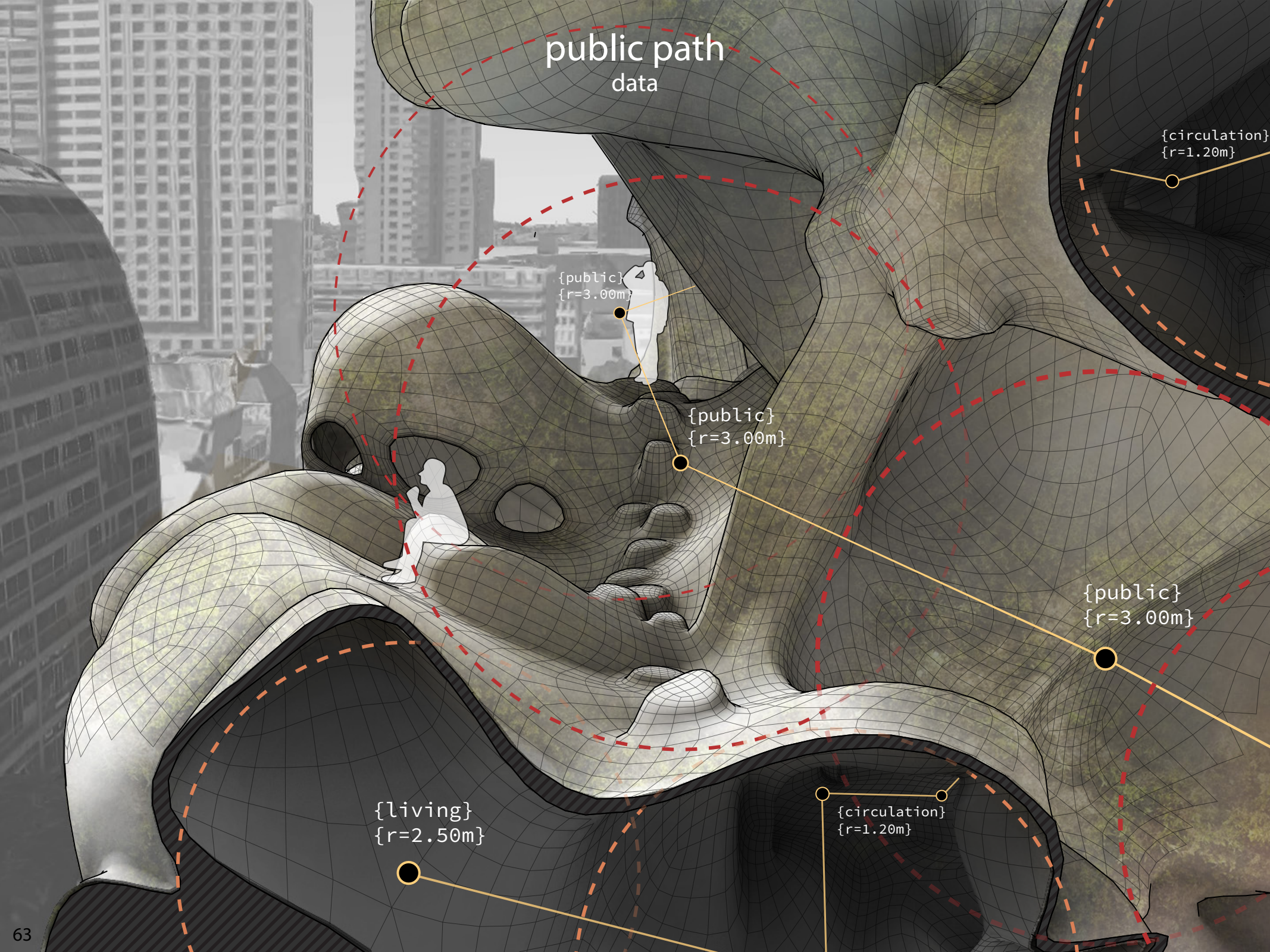
Convex weighted voronoi
mesh [relatively large sphere]

facade

concave + convex




public path


public path
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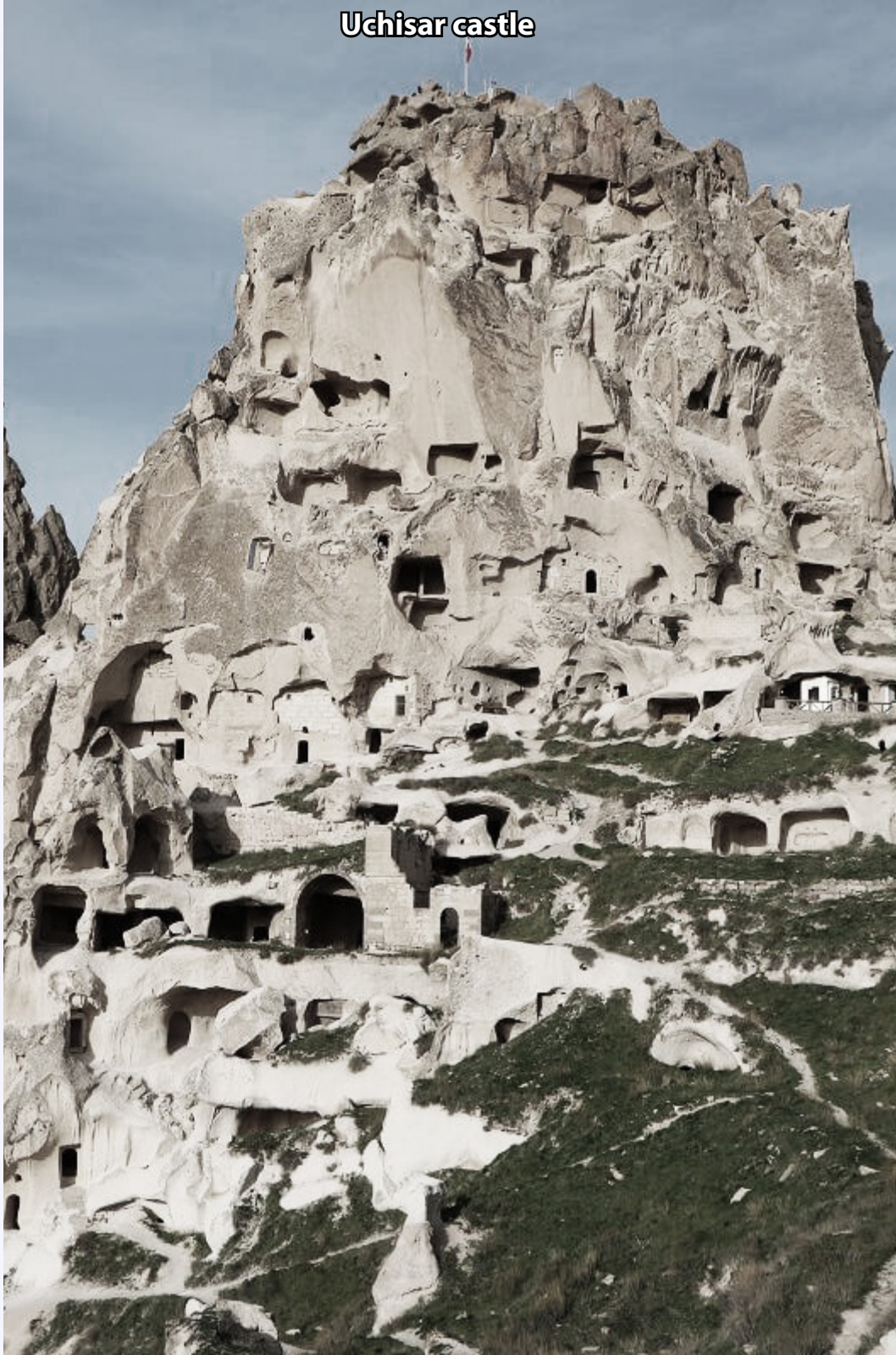
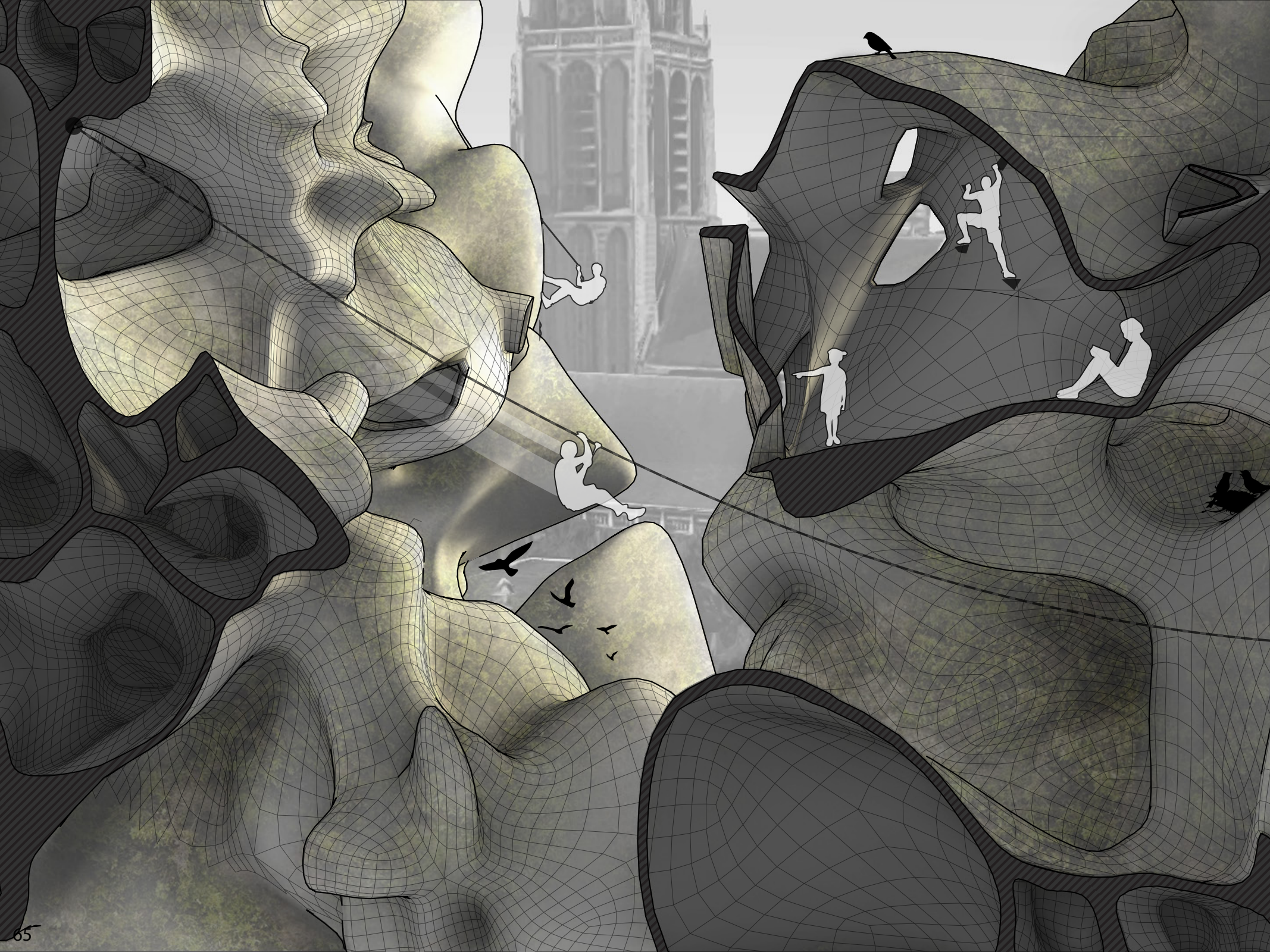
Kandovan

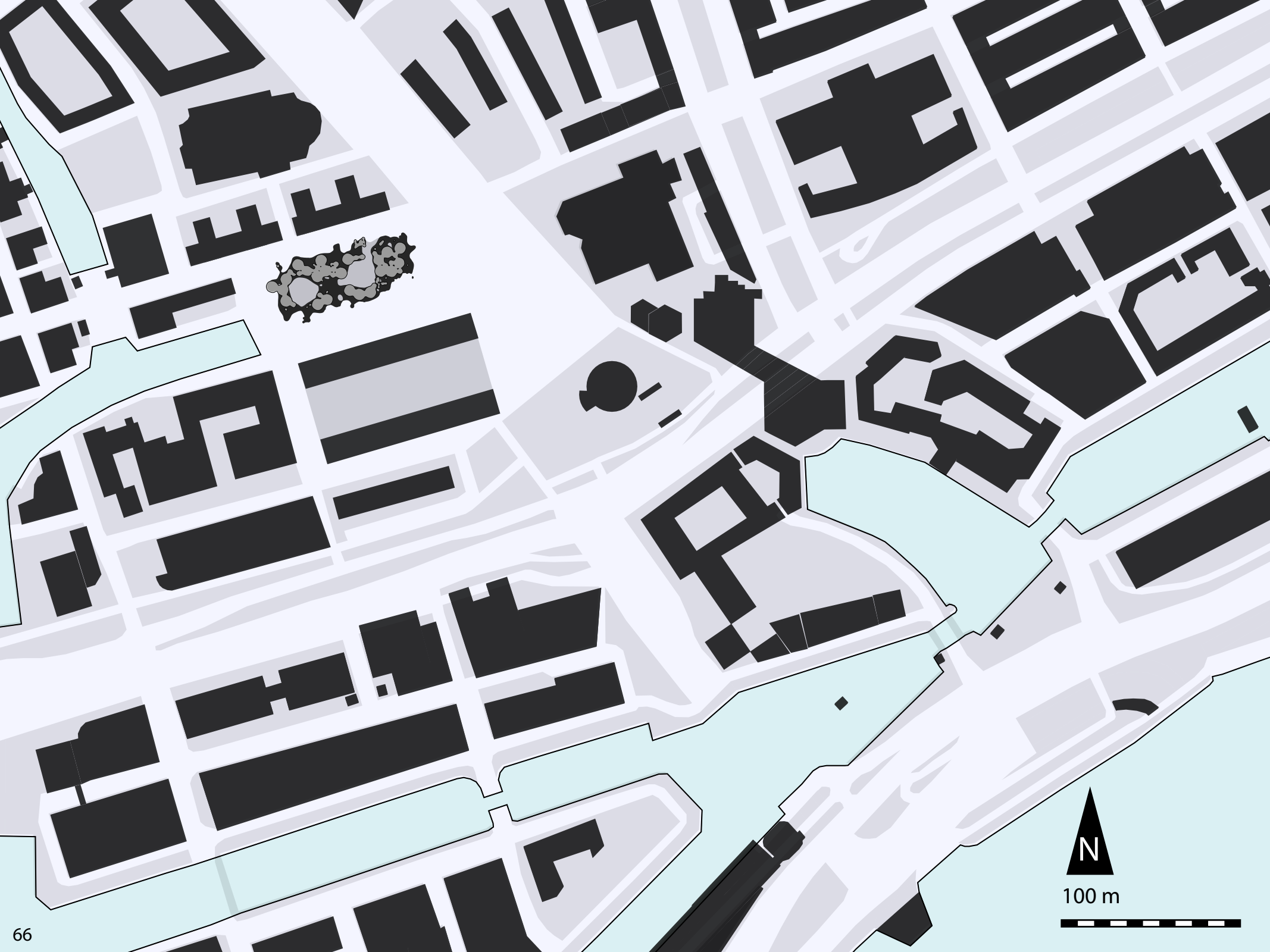


Vardzia



Uchisar castle



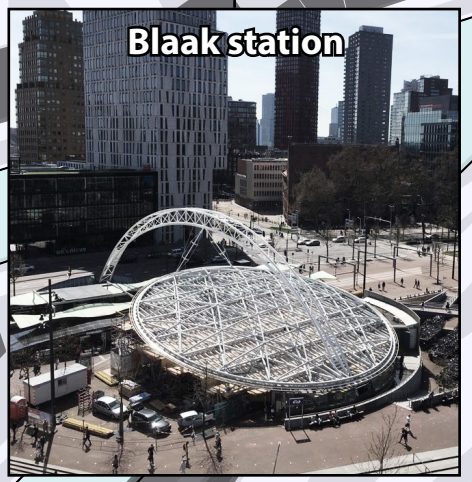

N
100 m

Rotterdam Blaak

area of architectural experiments

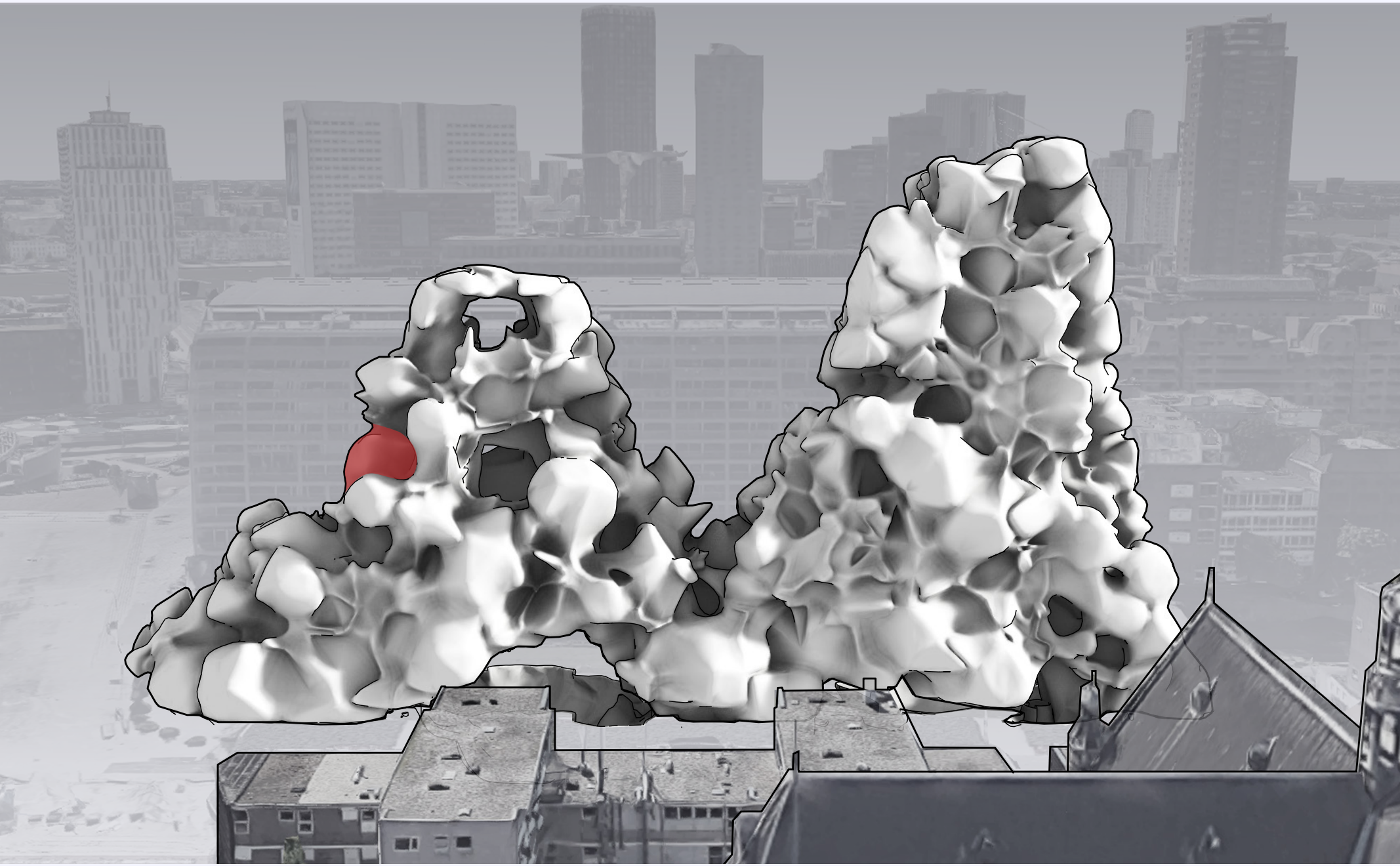




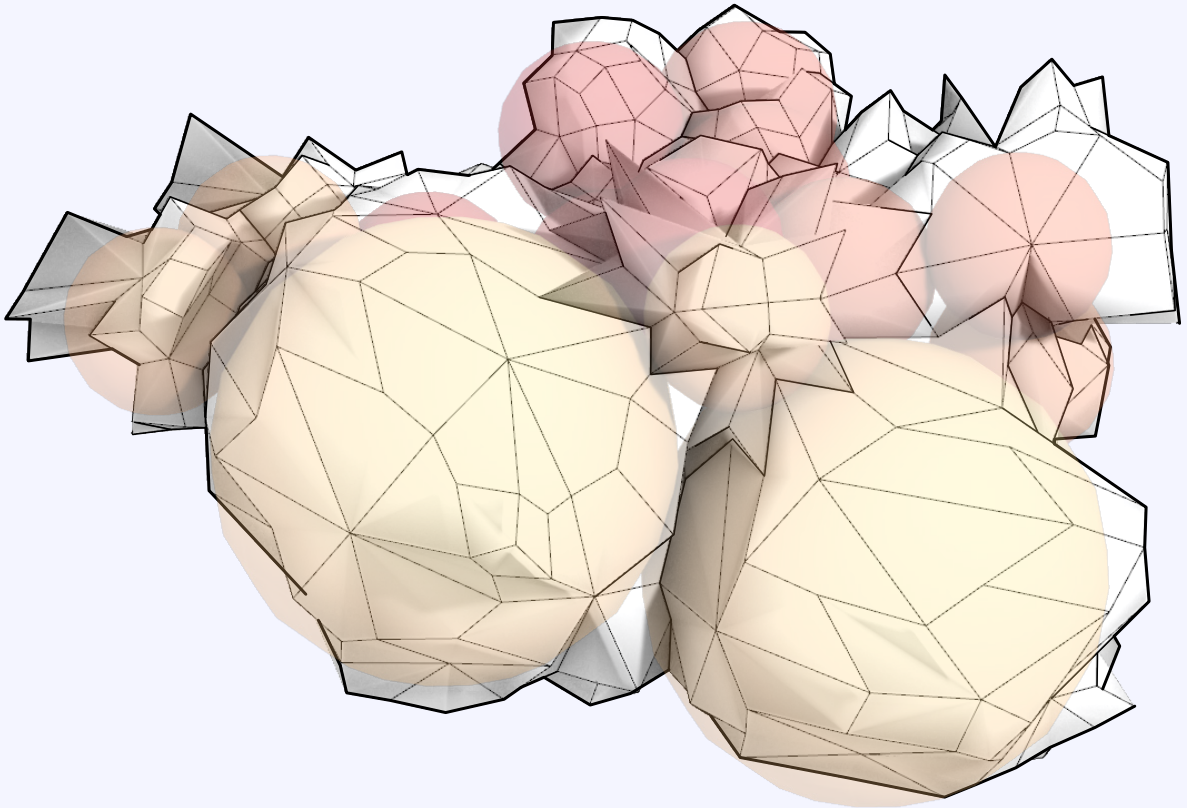




apartment scale

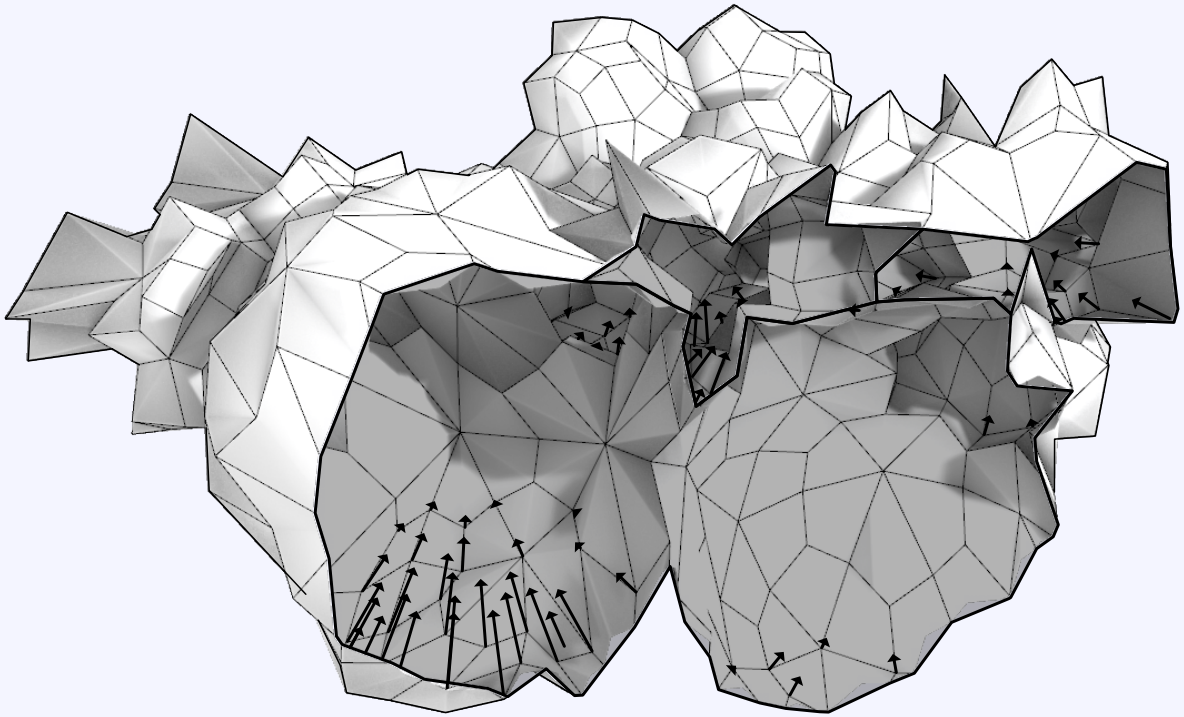


3D weighted voronoi output

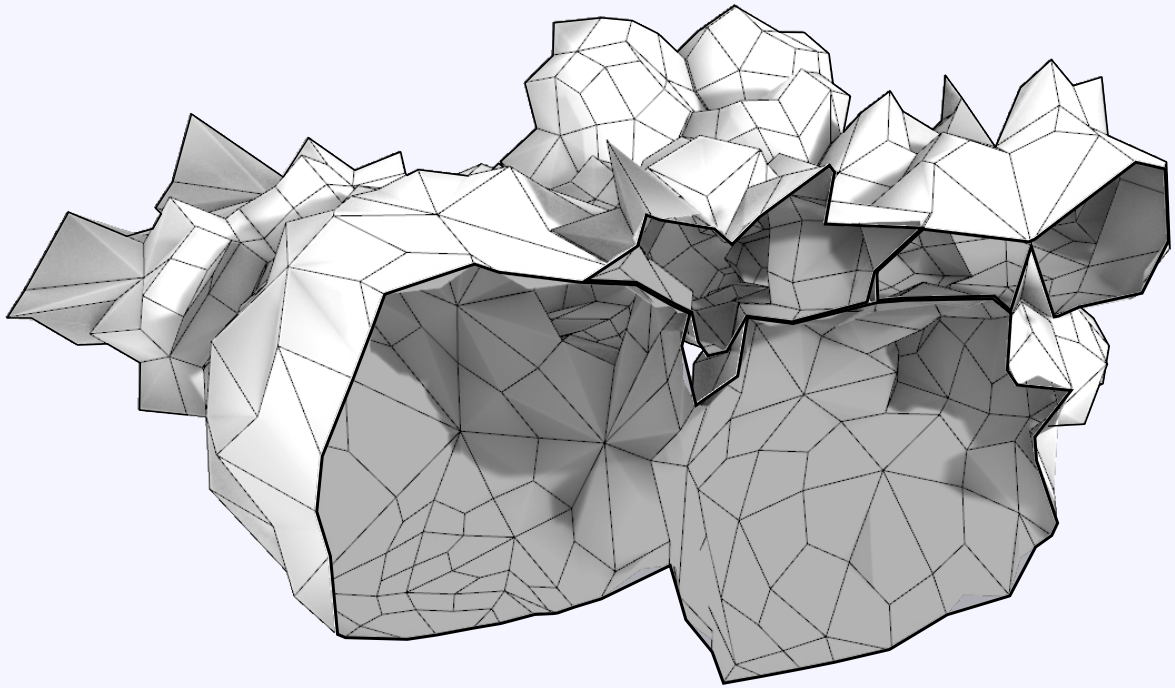


rationalization

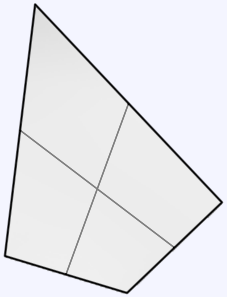
floor planarization

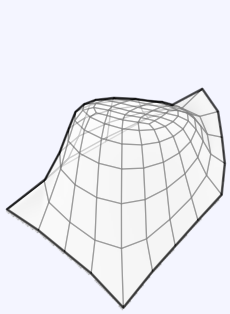


rationalization

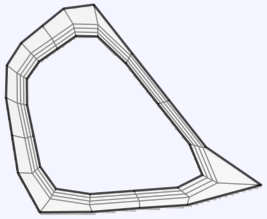


replace mesh faces with functions

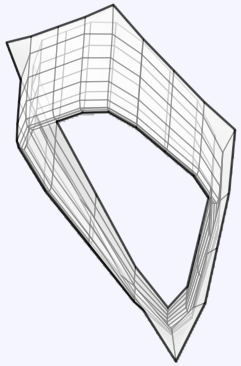




step



internal window



external window

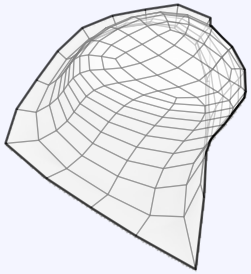
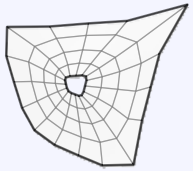
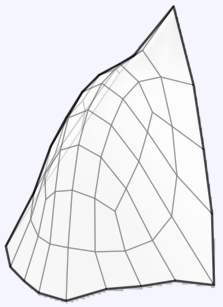


table +seating

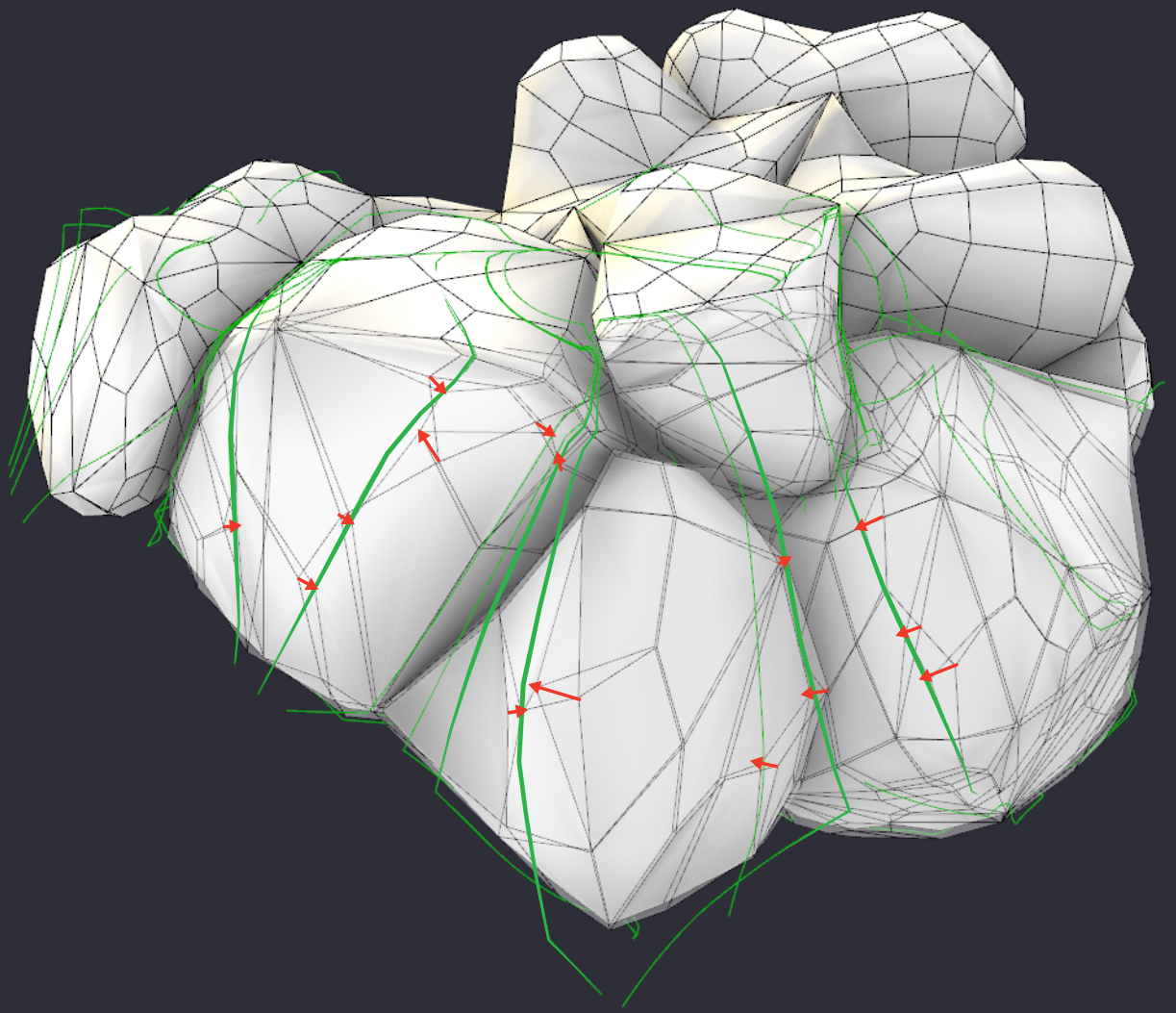


ventilation



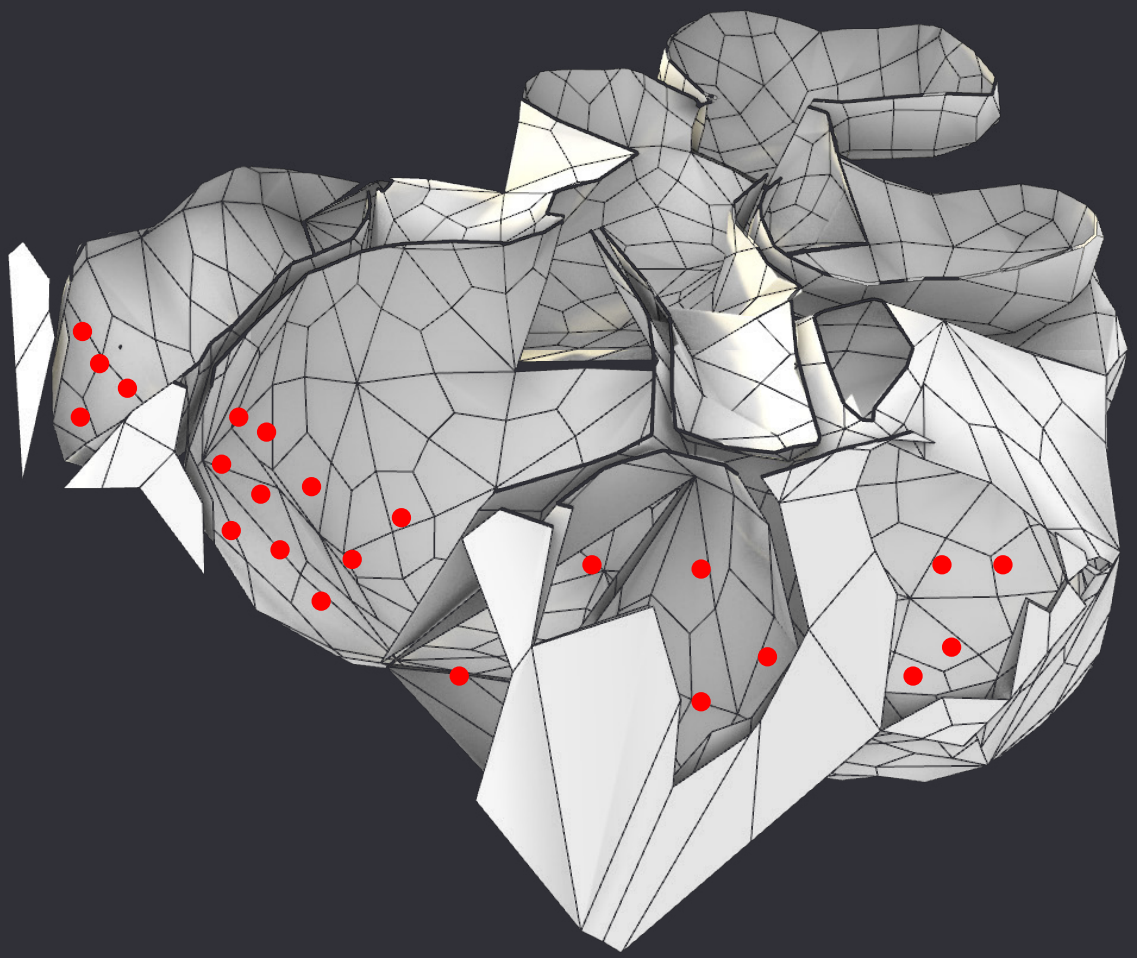
balustrade

mesh adaptation based on forceflow

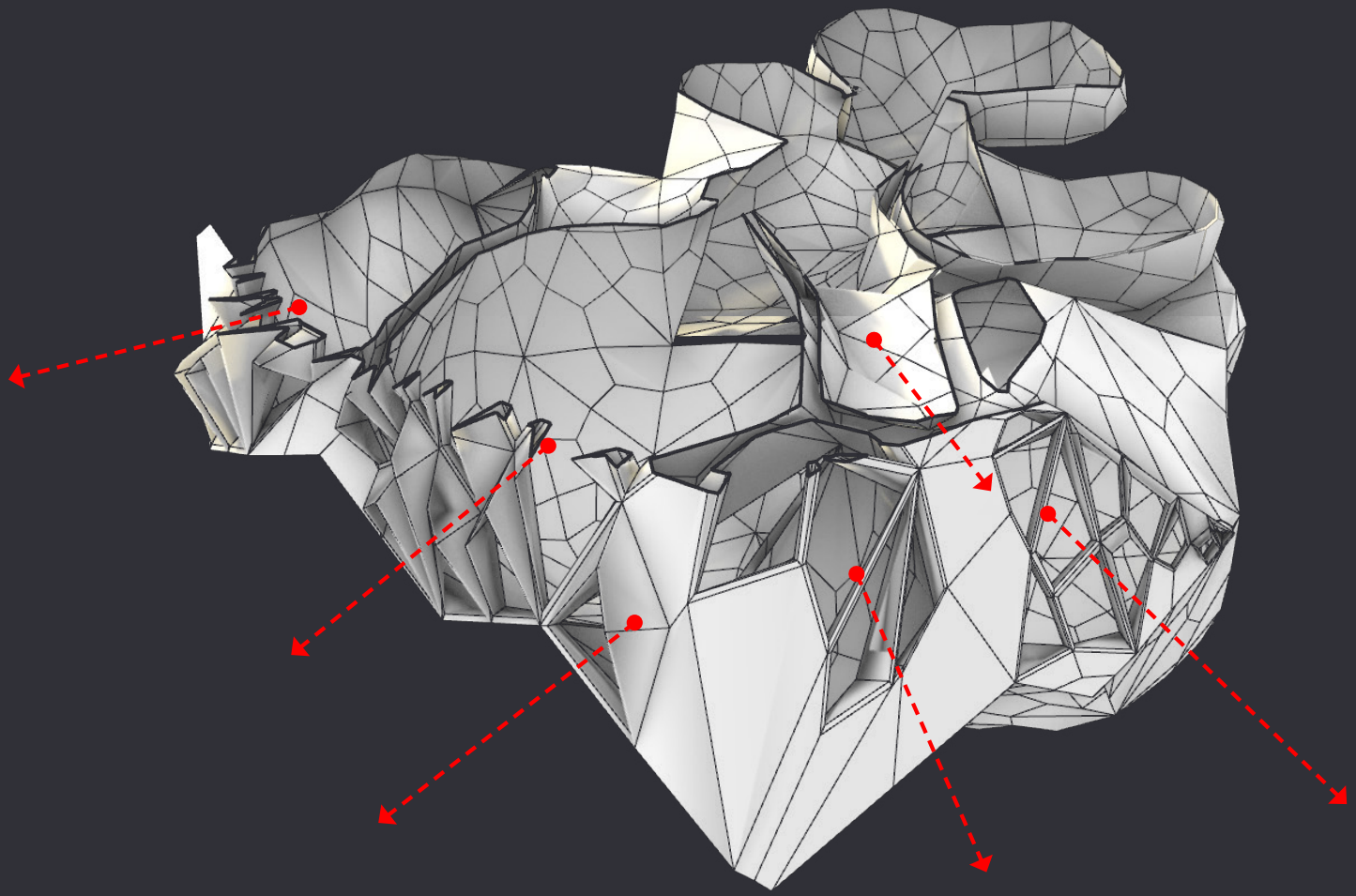


window faces

towards outside - overlap with facade

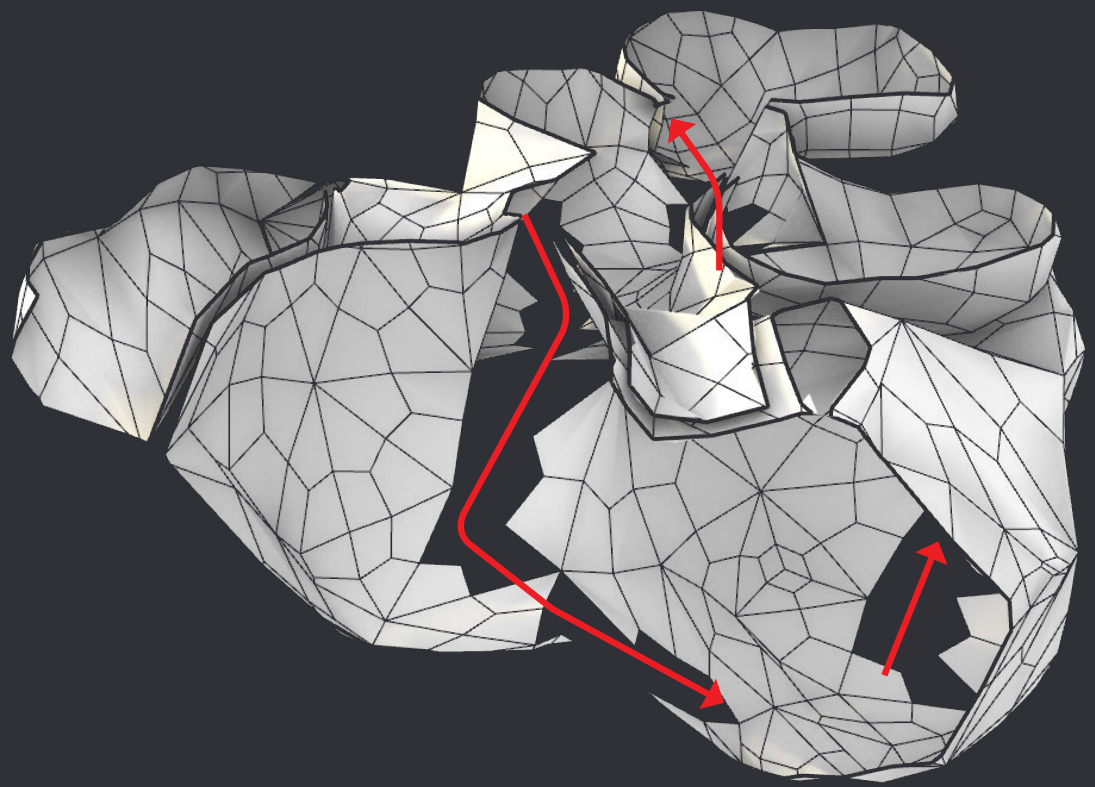


window faces

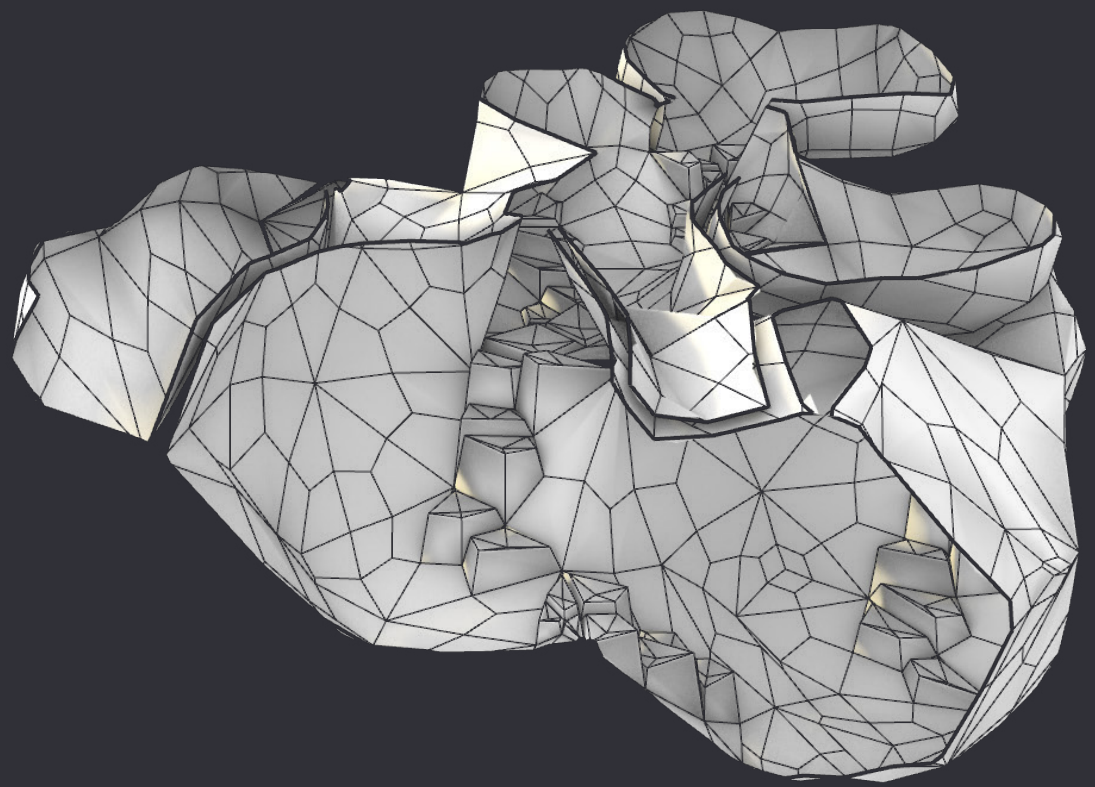


step faces

based on path curves & inclination

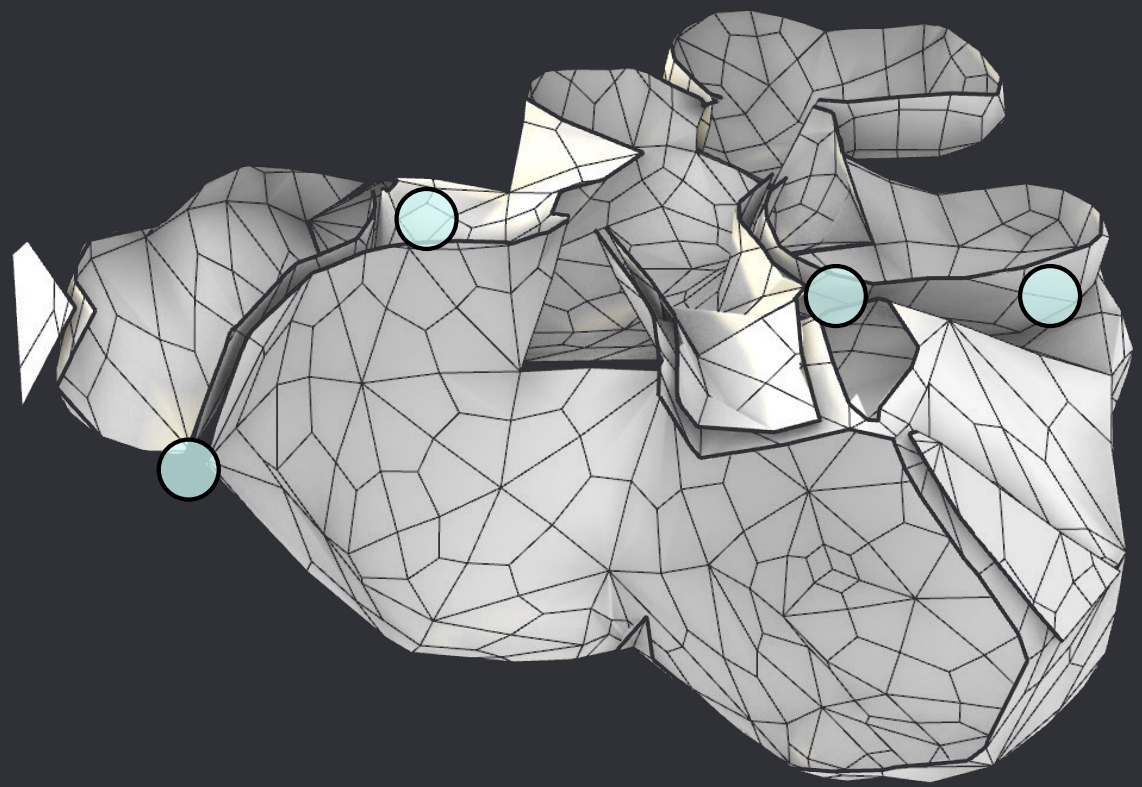


step faces

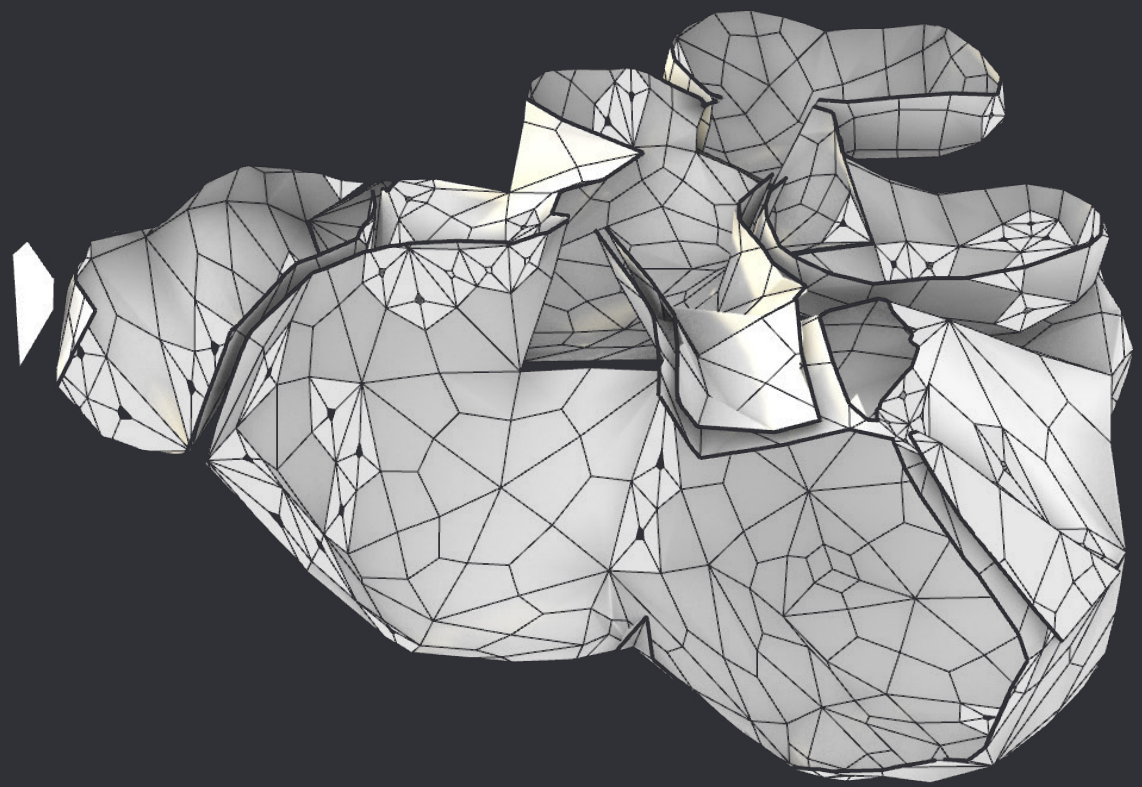


ventilation faces

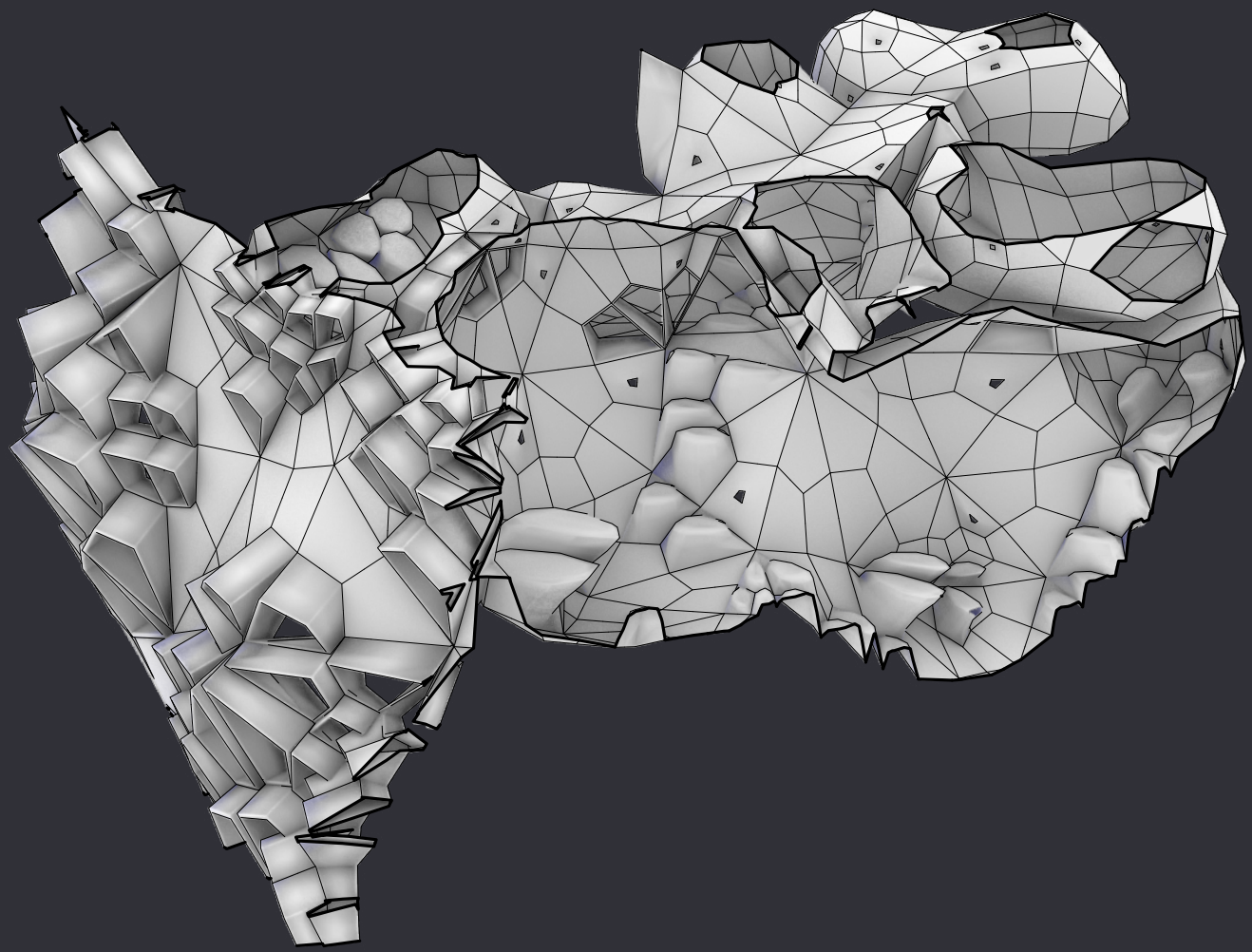
close to cavities between shells



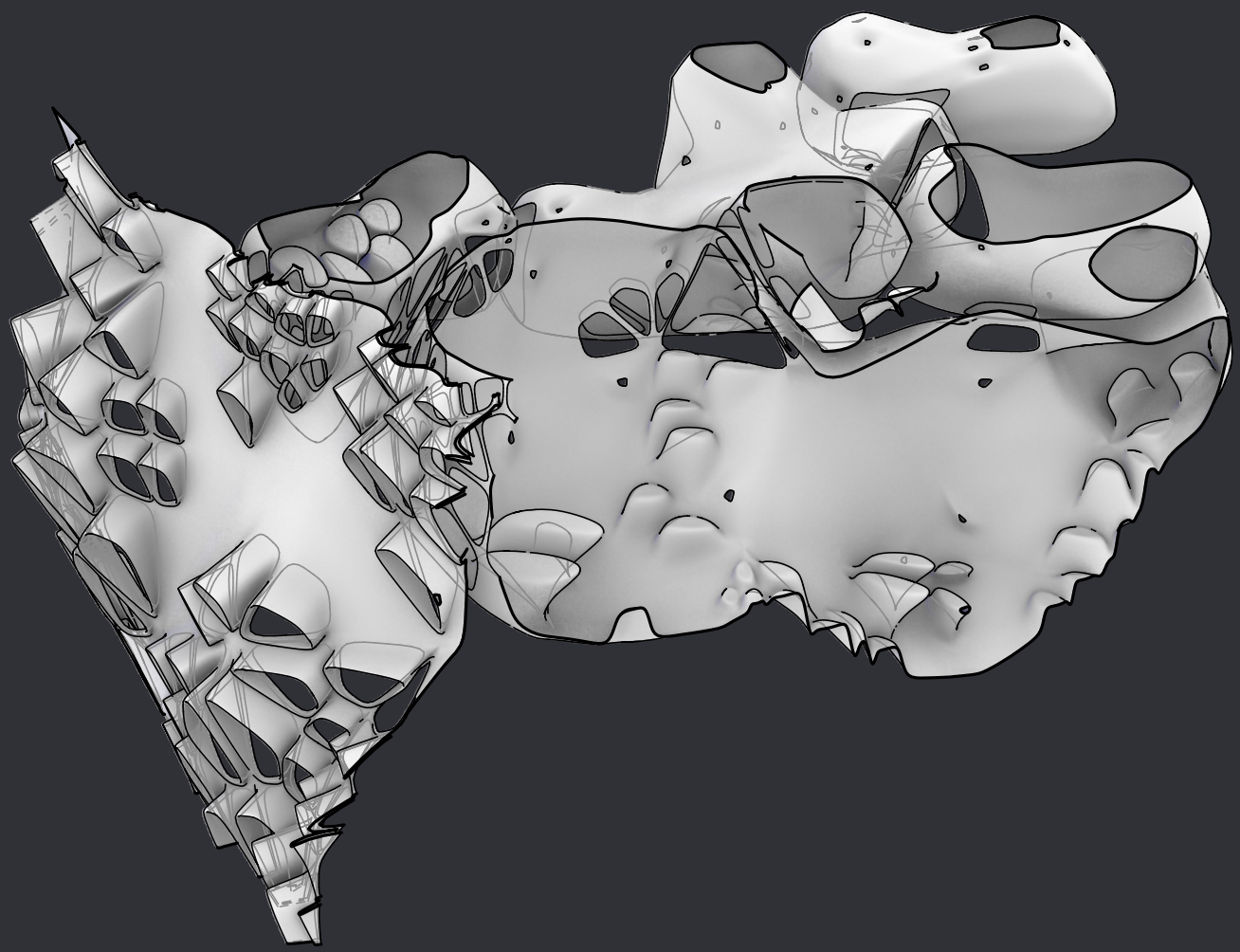
ventilation faces



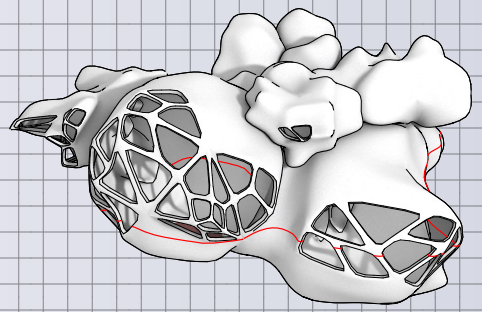
all faces replaced



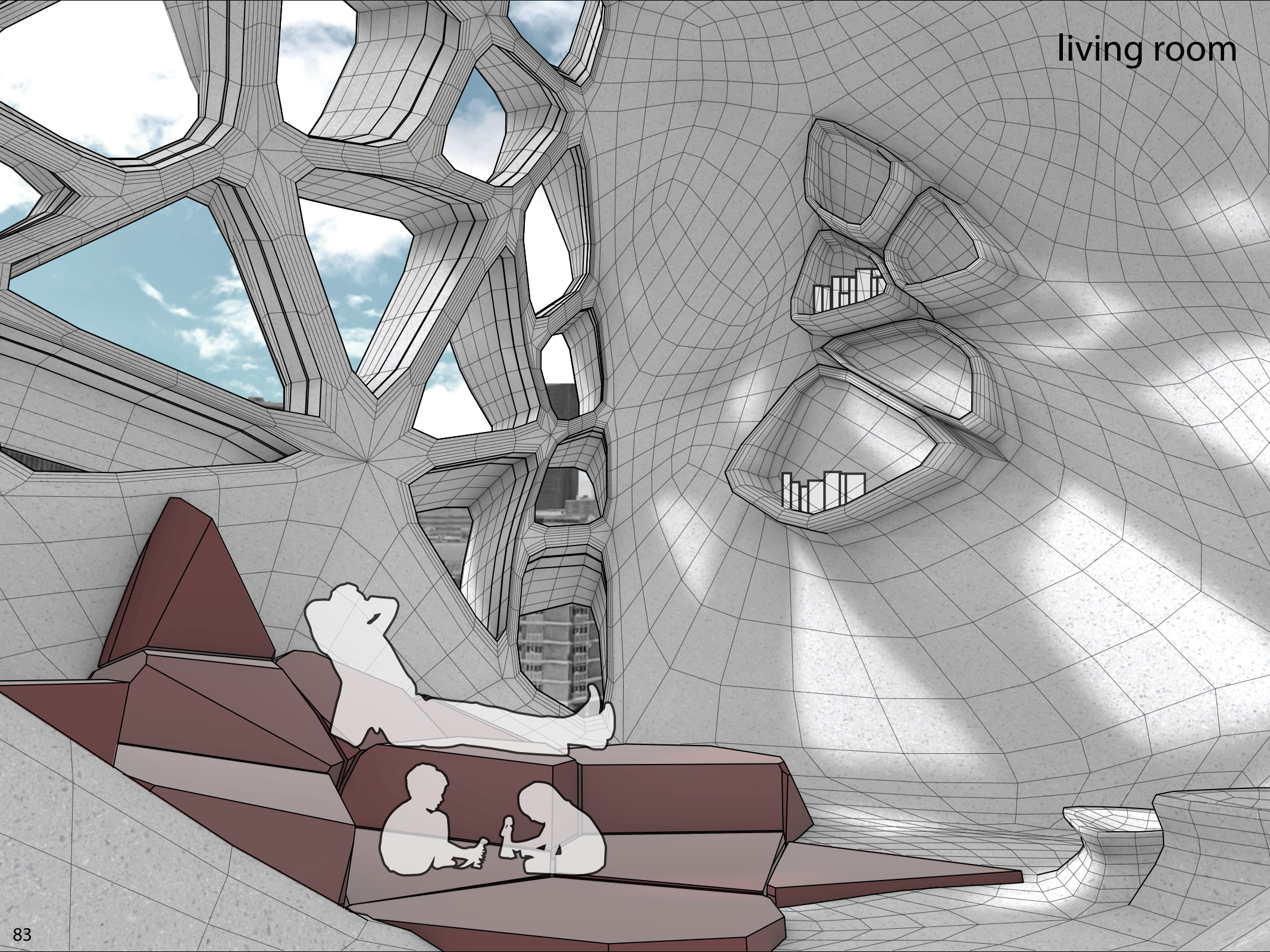
smoothing

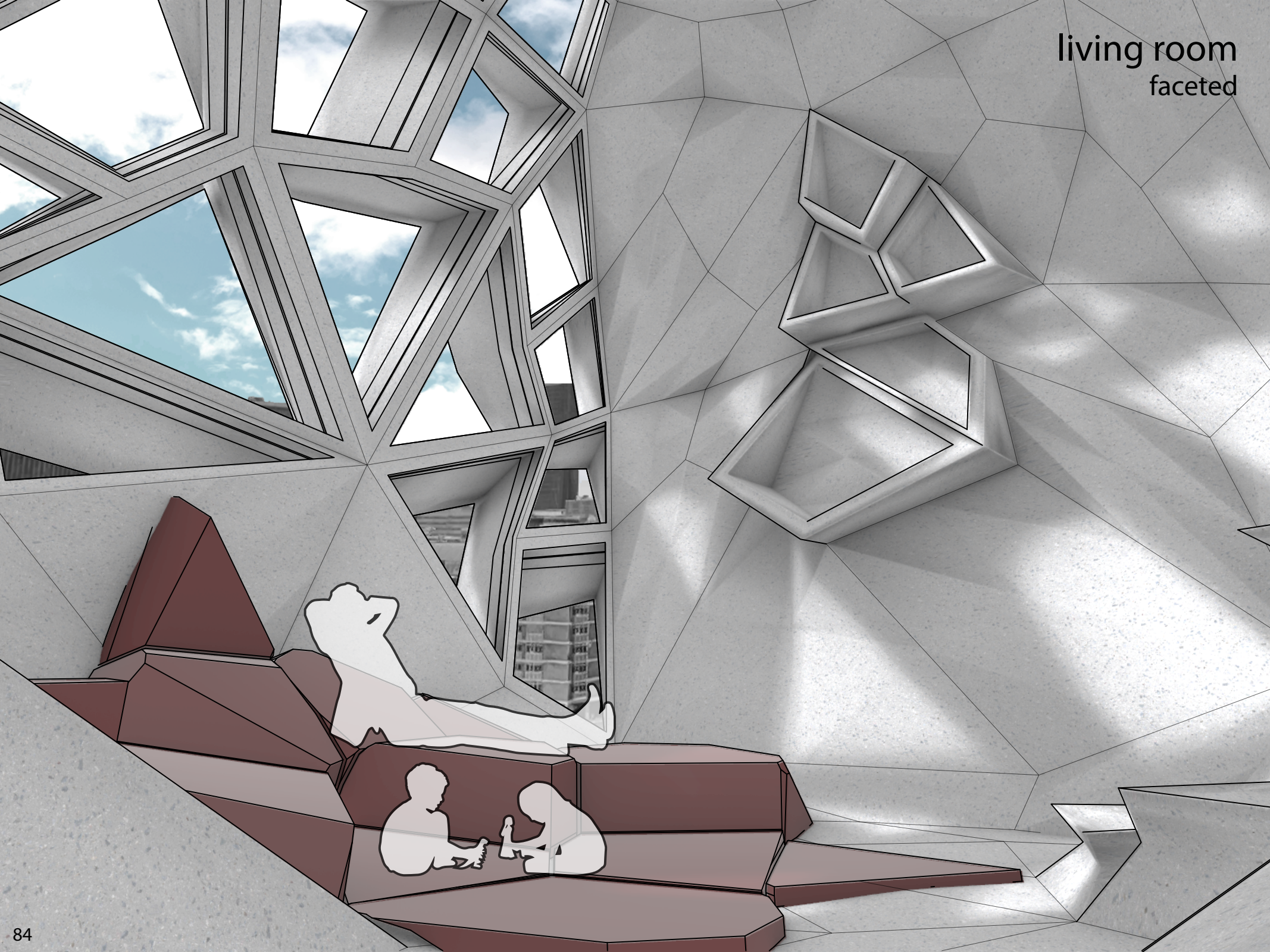


plan 1:100

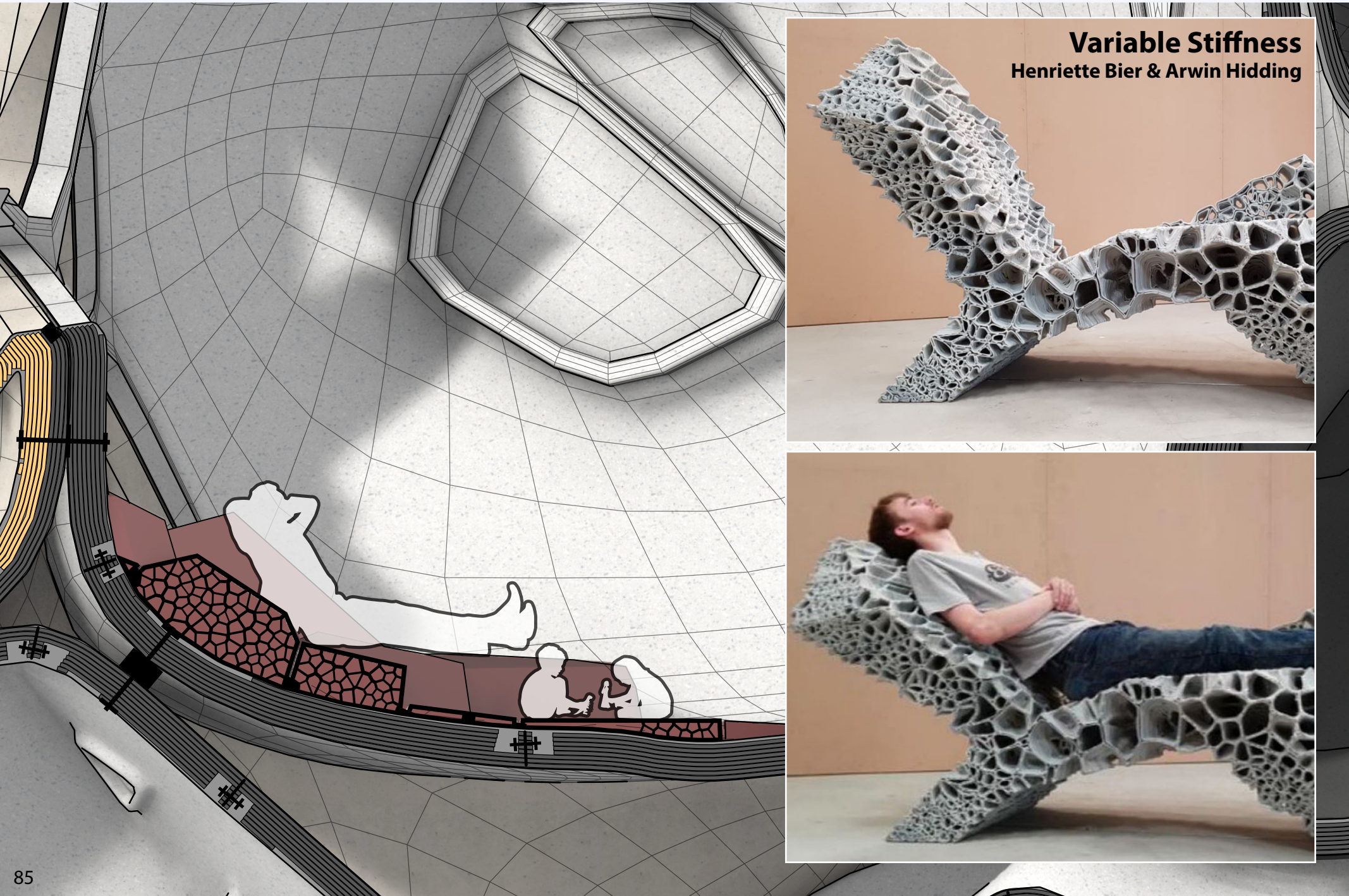


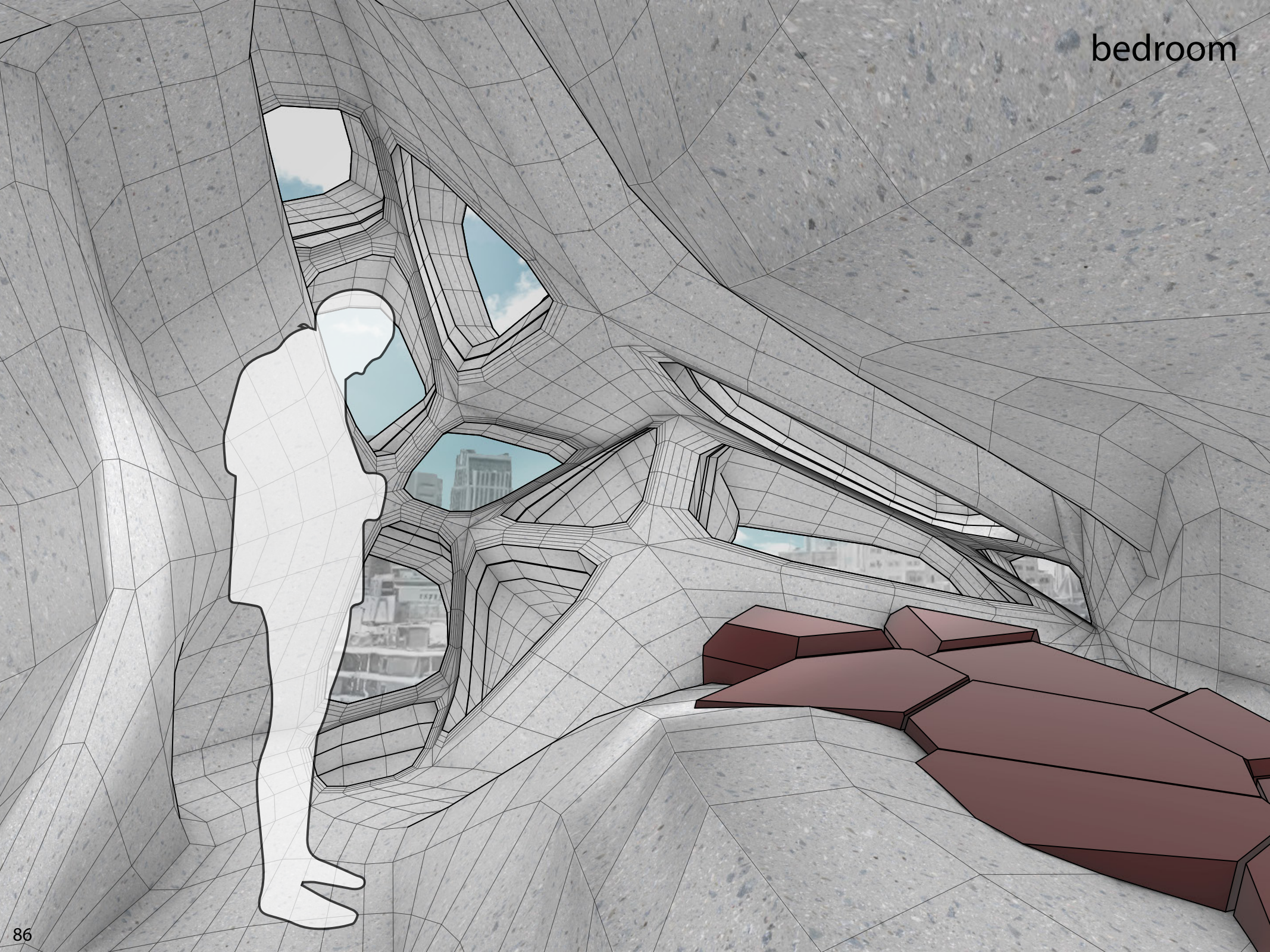
1000 mm

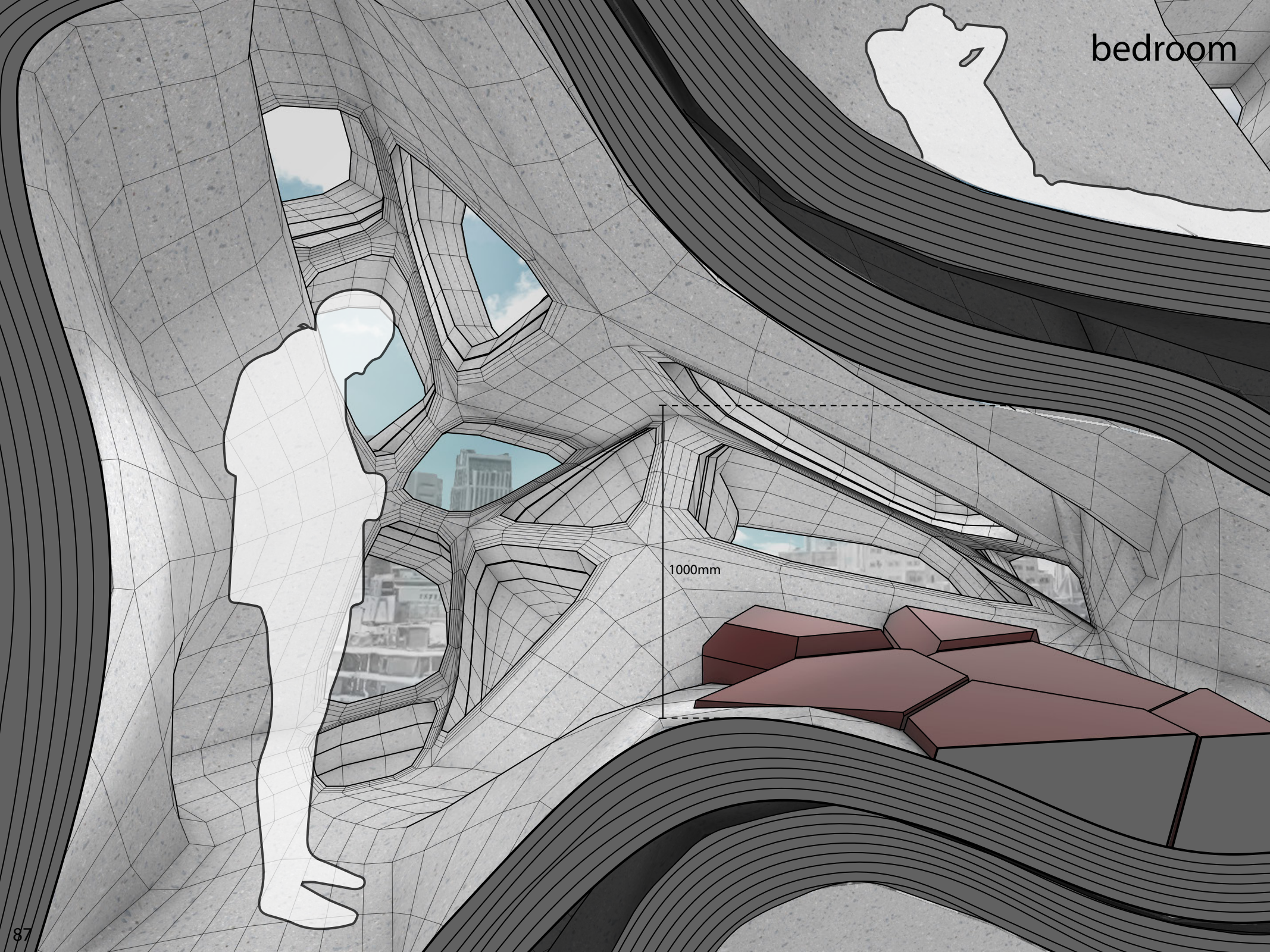

living room


living room
faceted

soft furniture through printing morphology




bedroom


bedroom
1000mm

interior reference

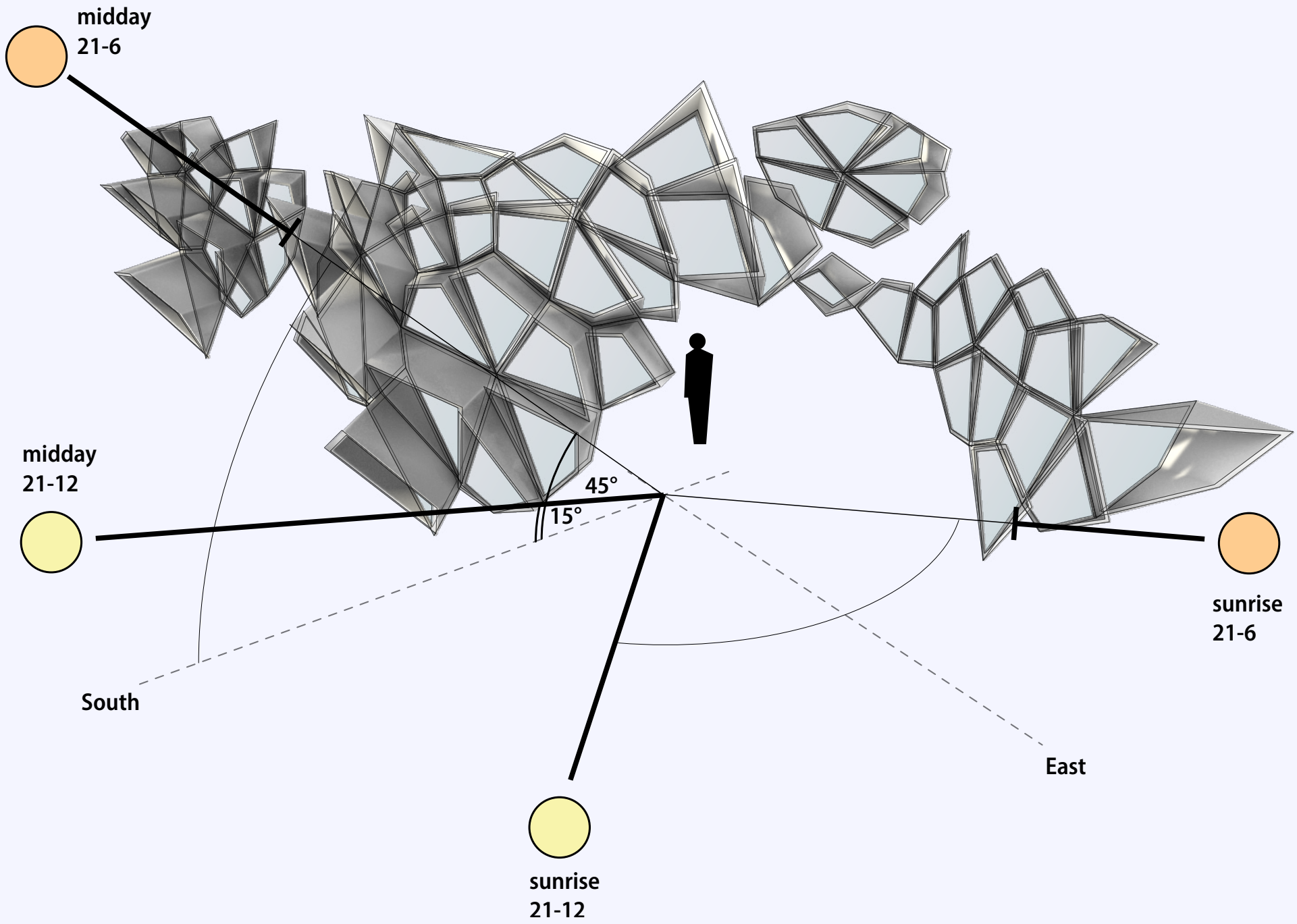


interior reference

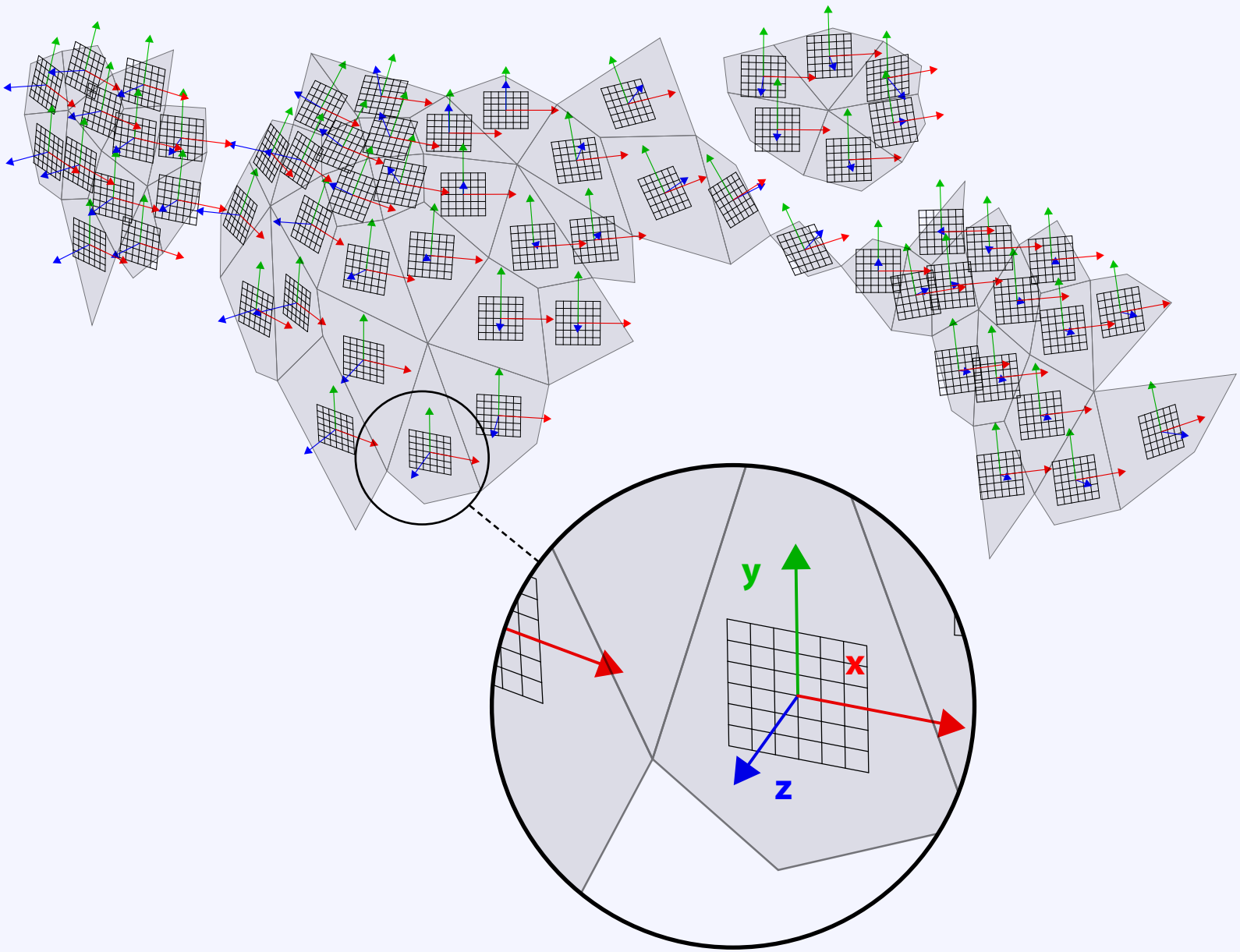


Jogasaki Coast
Izu peninsula, Japan

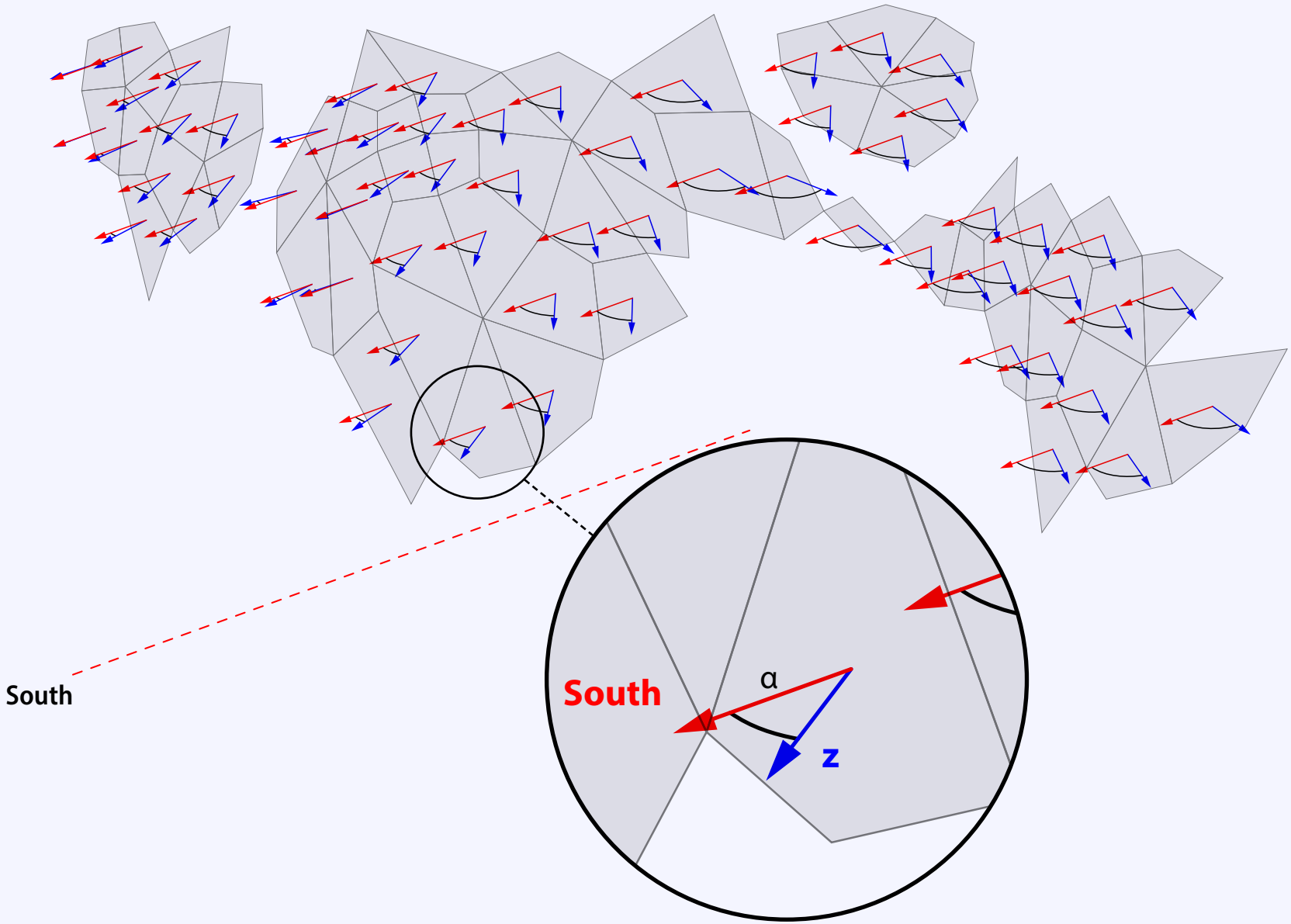
goal


midday
21-6
midday
21-12
45°
15°
sunrise
21-6
South
East
sunrise
21-12

window face planes

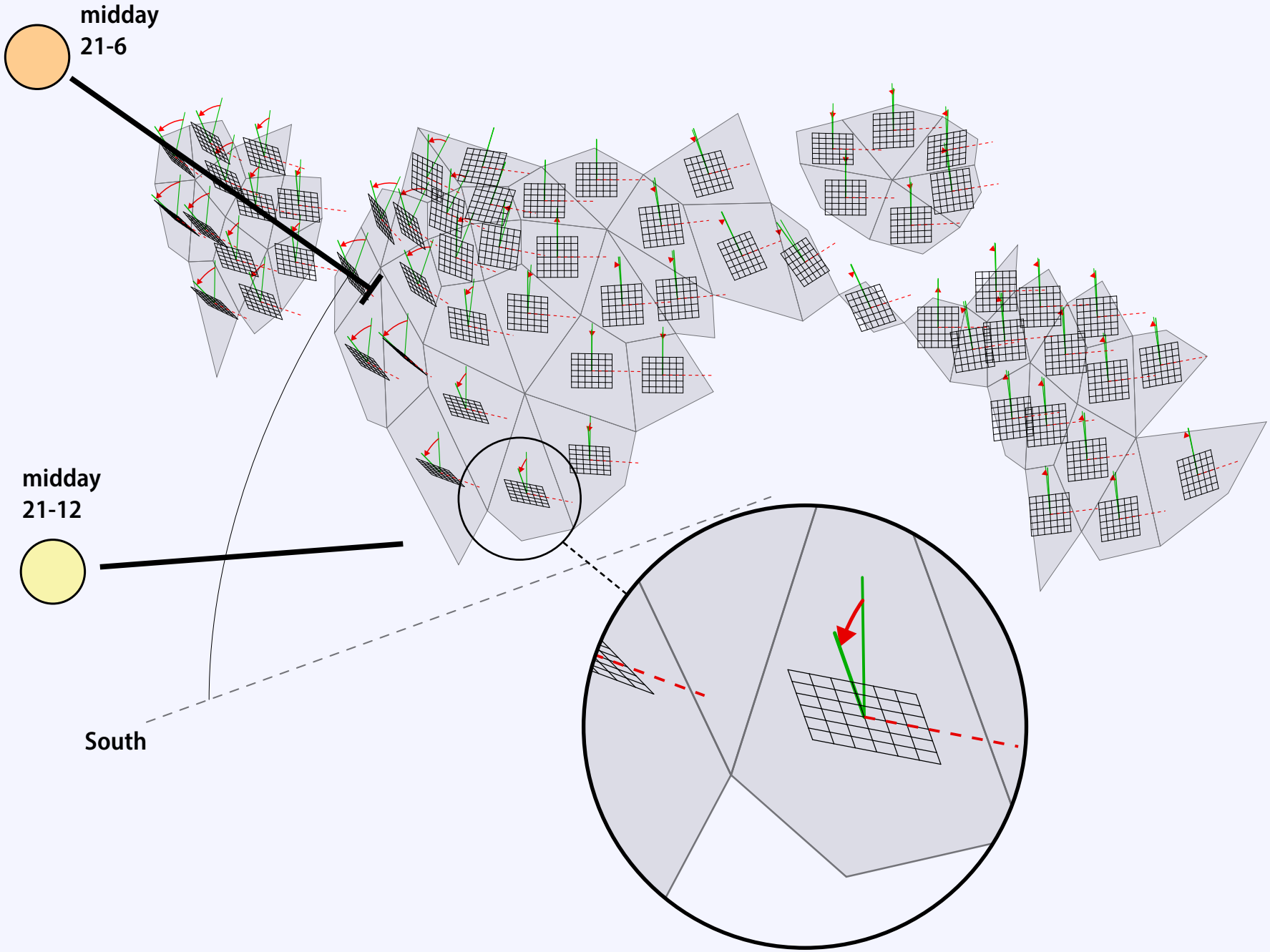


angle with south



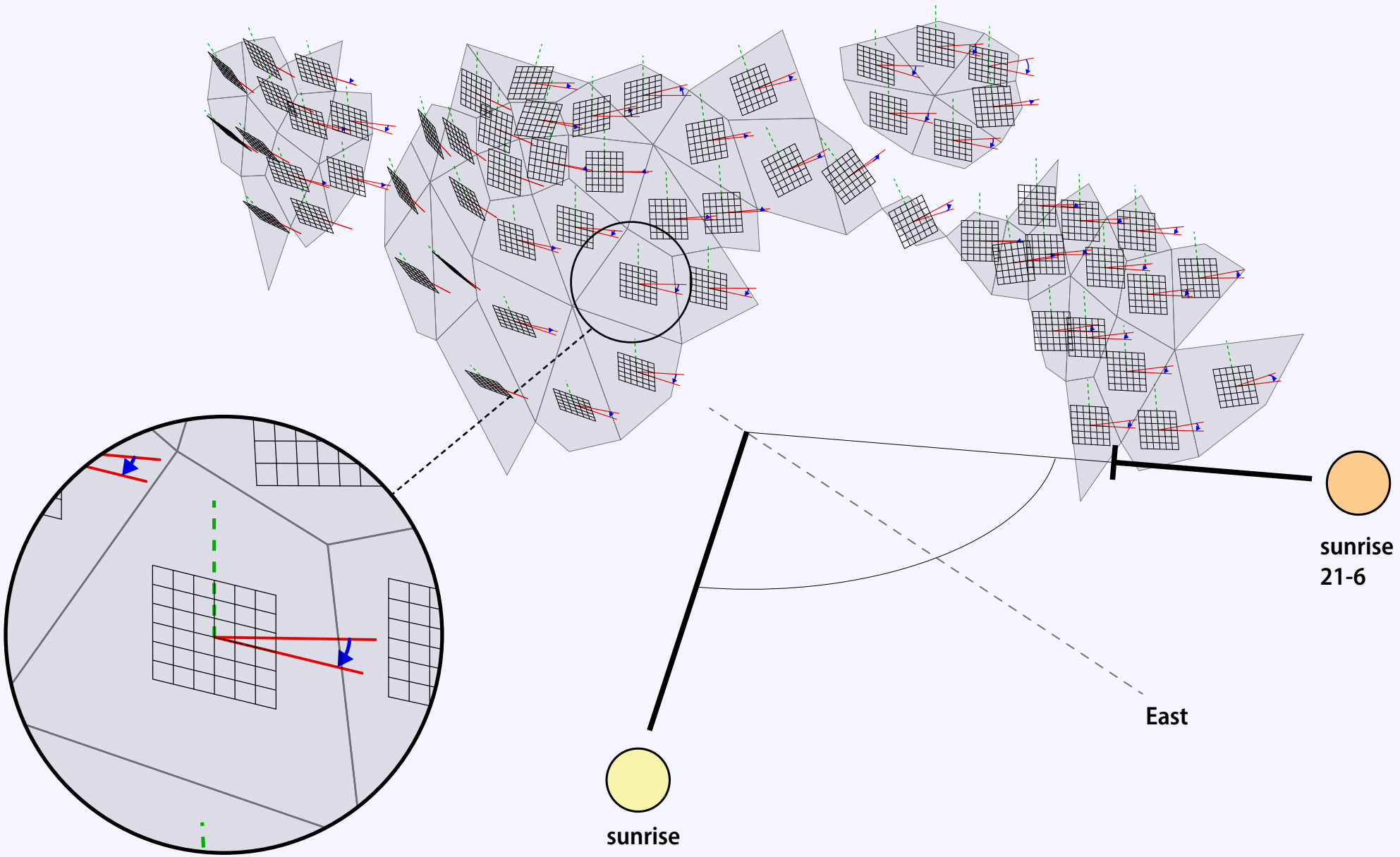
1st rotation

Along **x**-axis. South-facing planes get rotated more



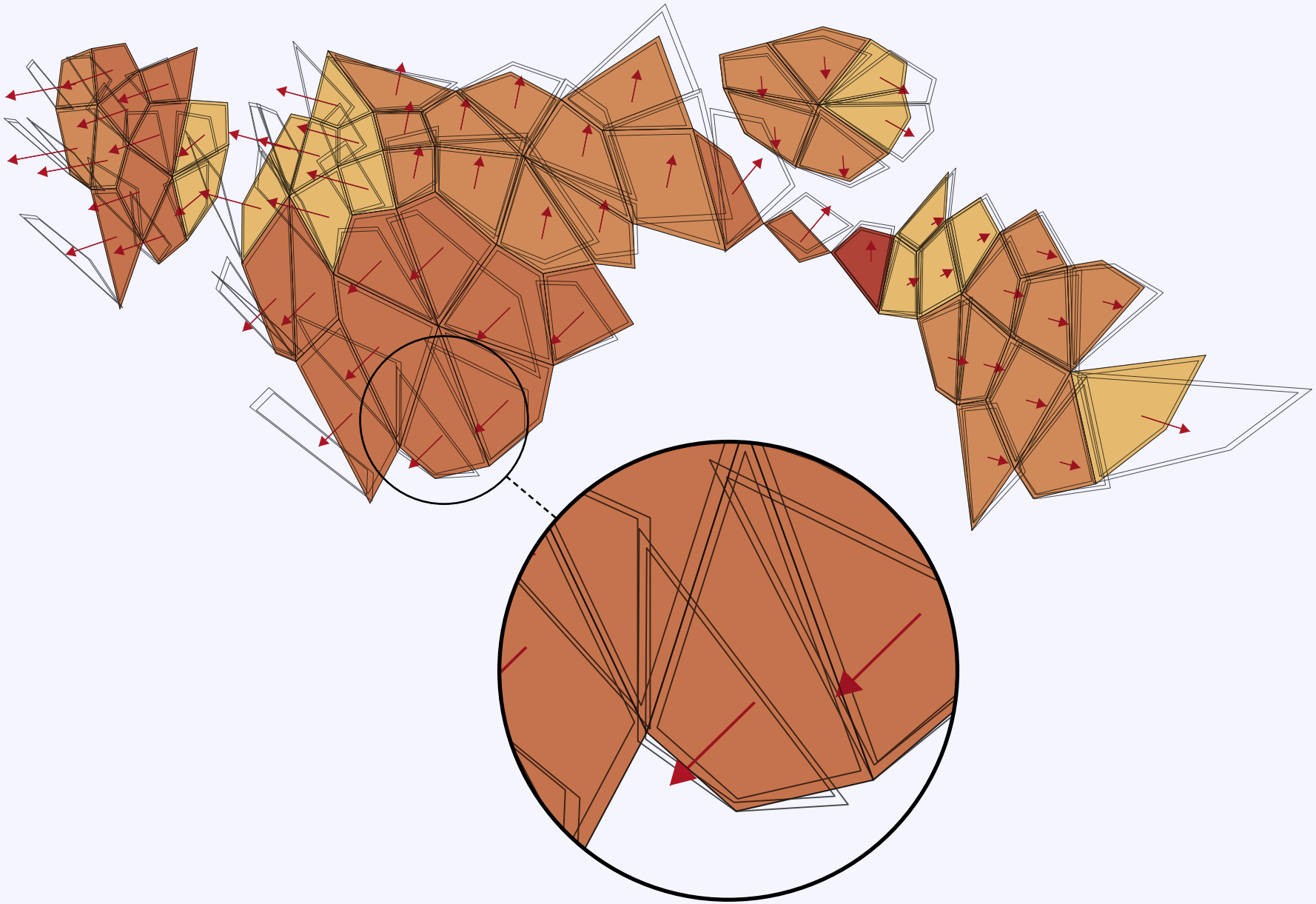
2nd rotation

Along **y**-axis. East & west -facing planes get rotated more.

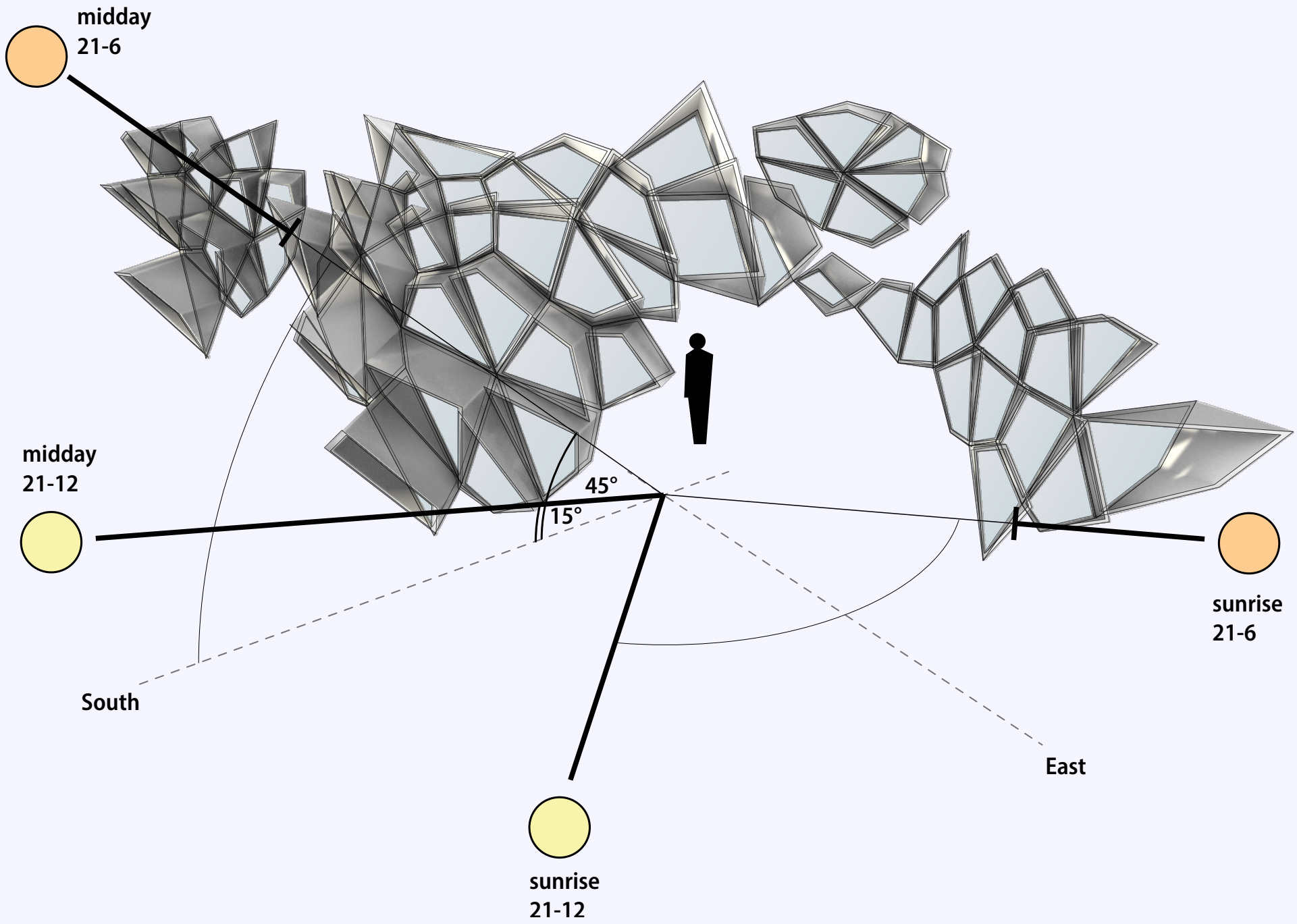


projection

Along average normal vectors per element. Allows for 3D printing.

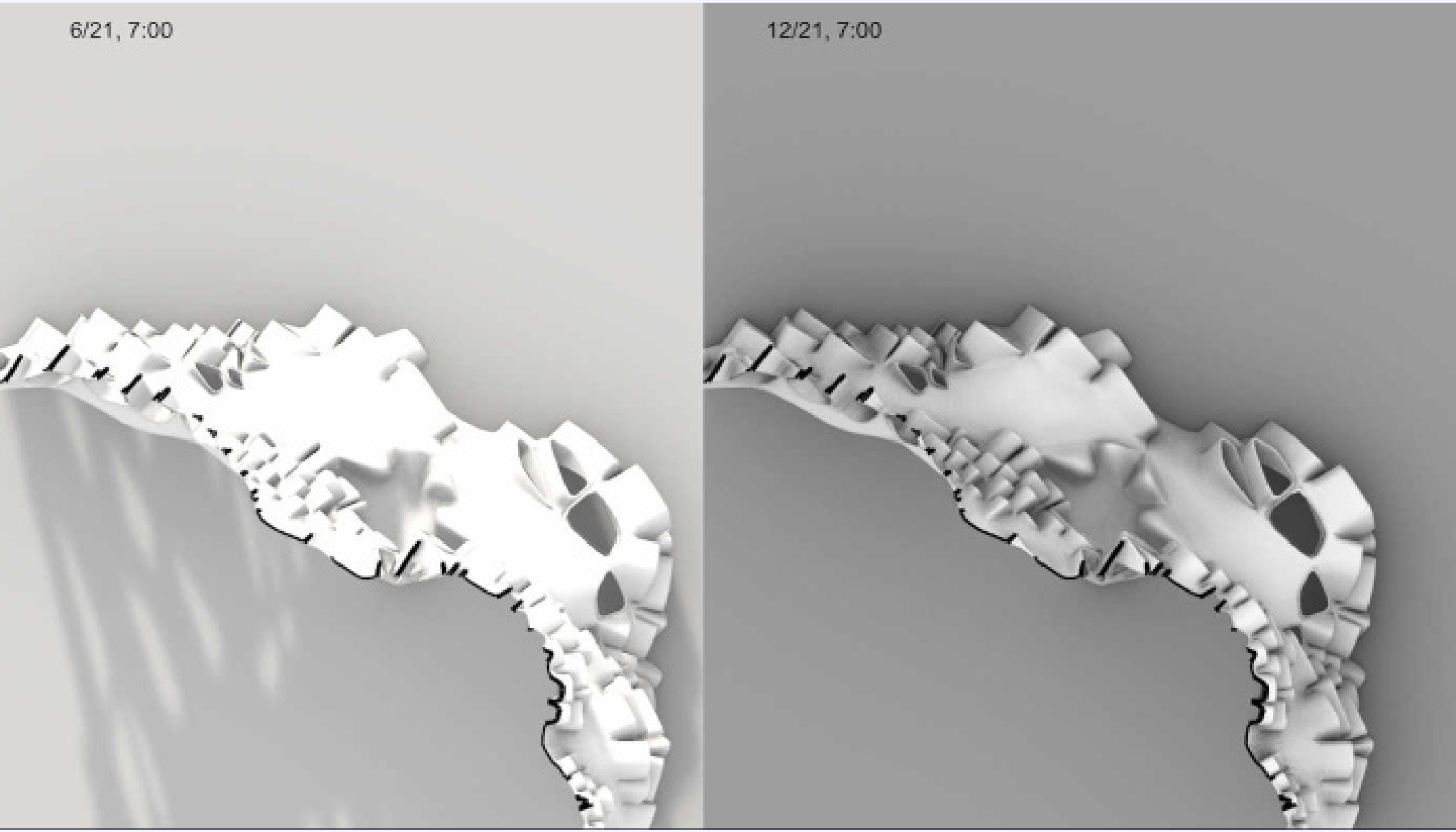


resulting geometry

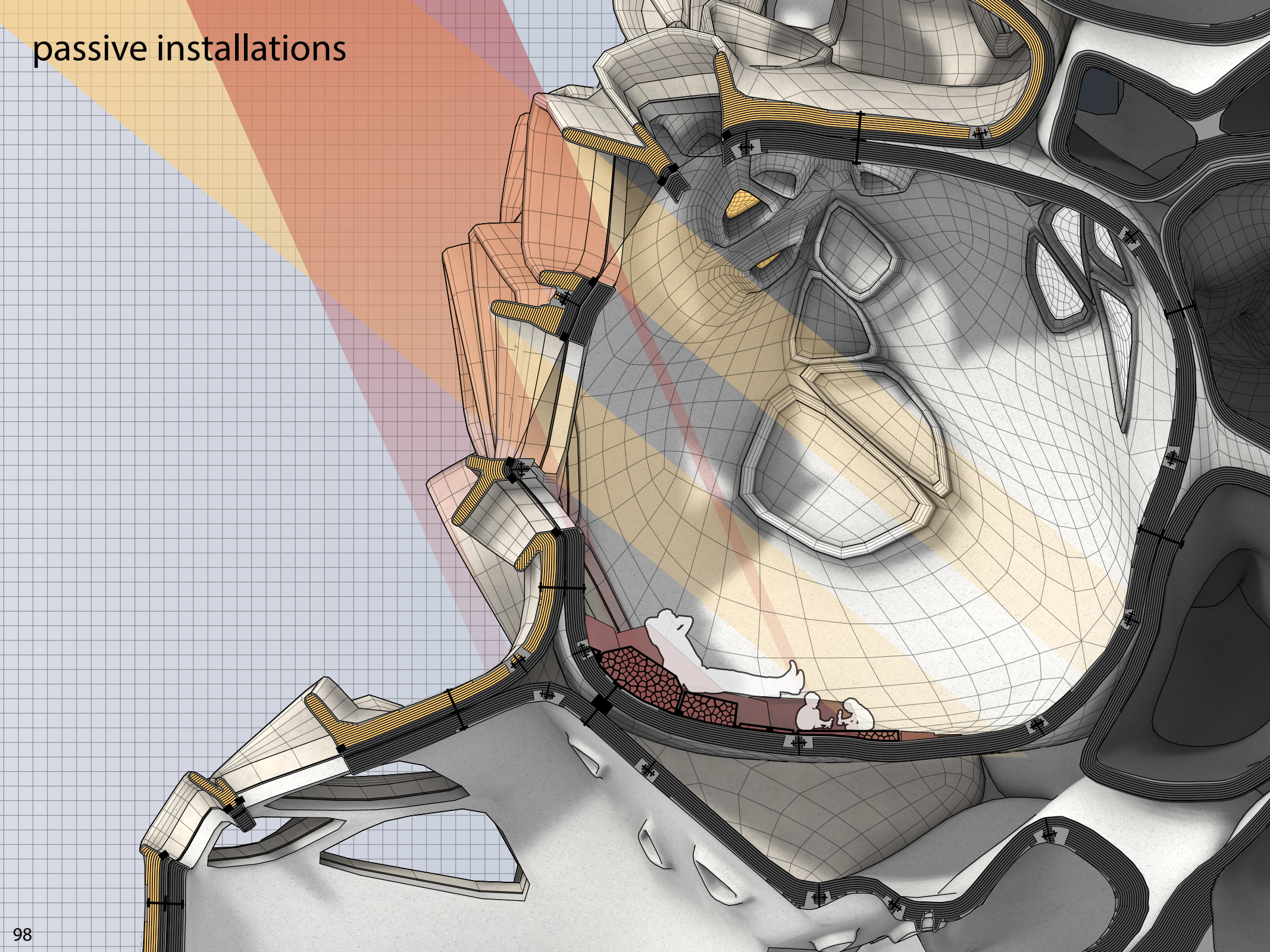


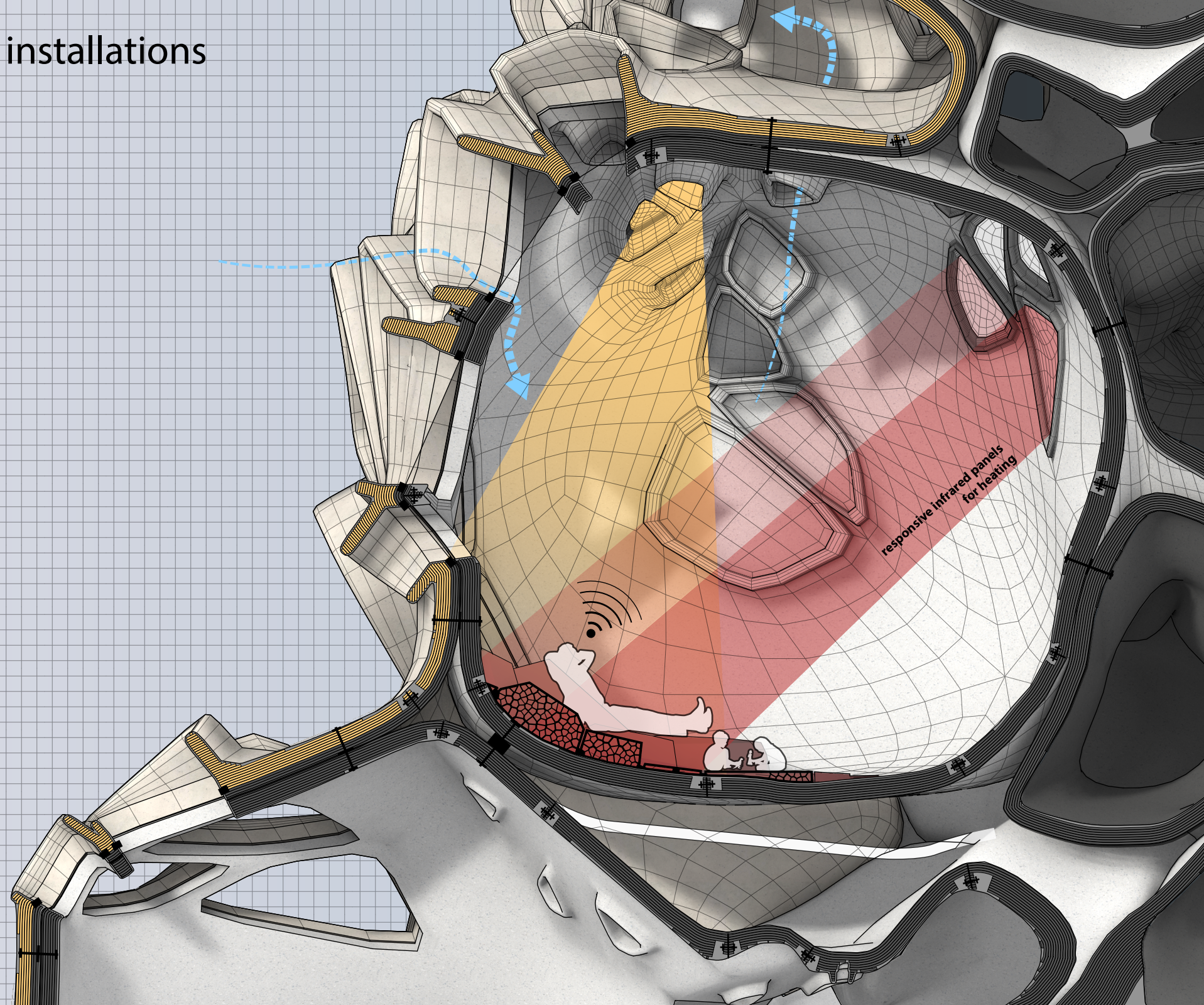
shading test

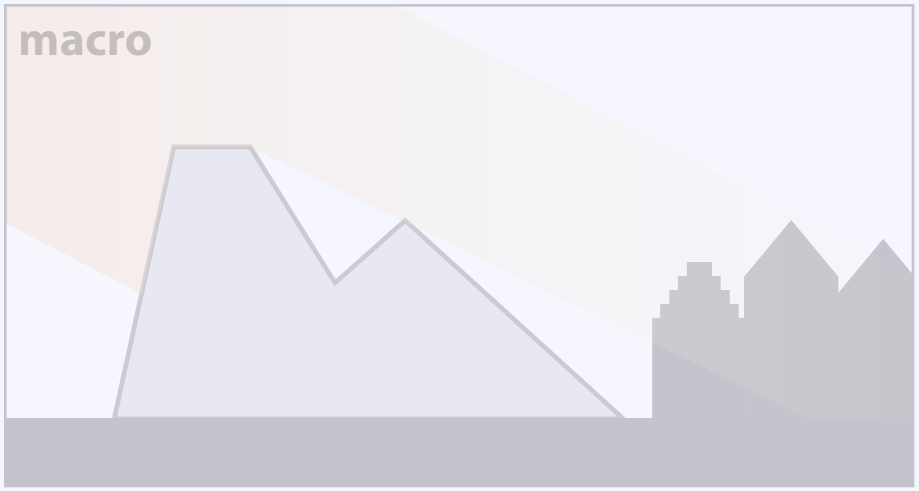
direct sunlight reduction in summer



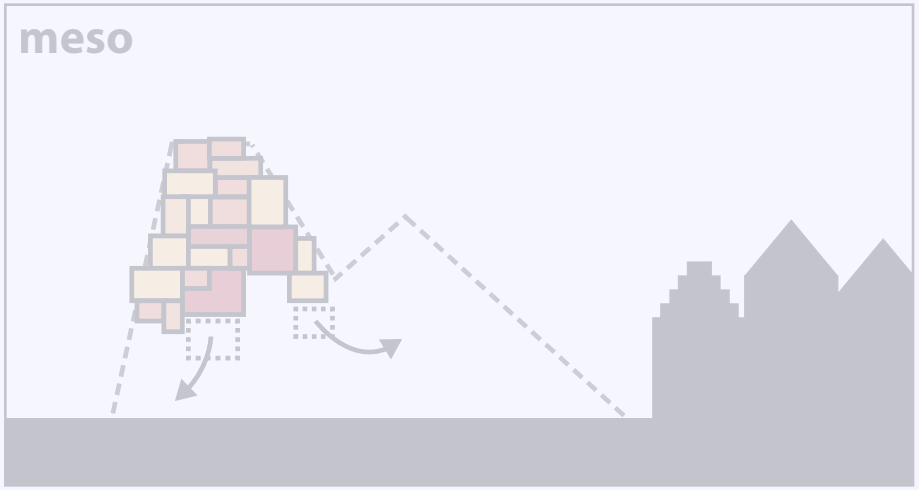
passive installations



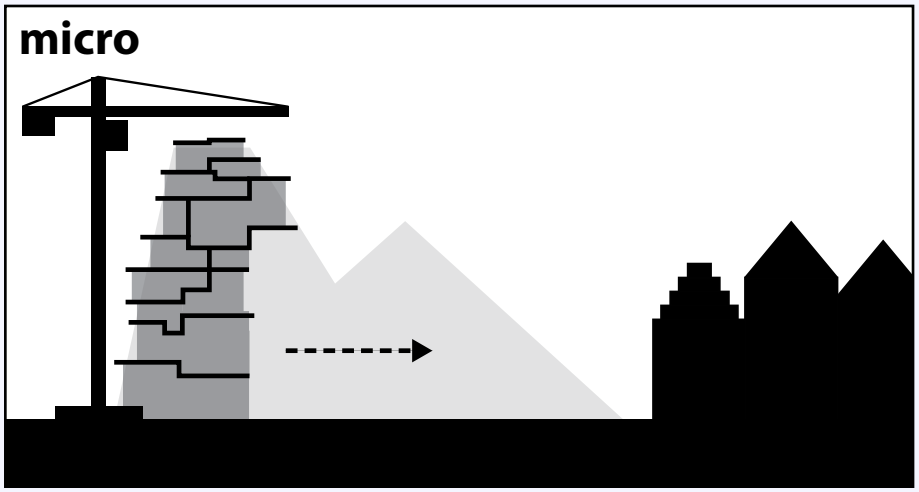

responsive infrared panels
for heating



Bounding volume based on solar access of adjacent buildings/public spaces.

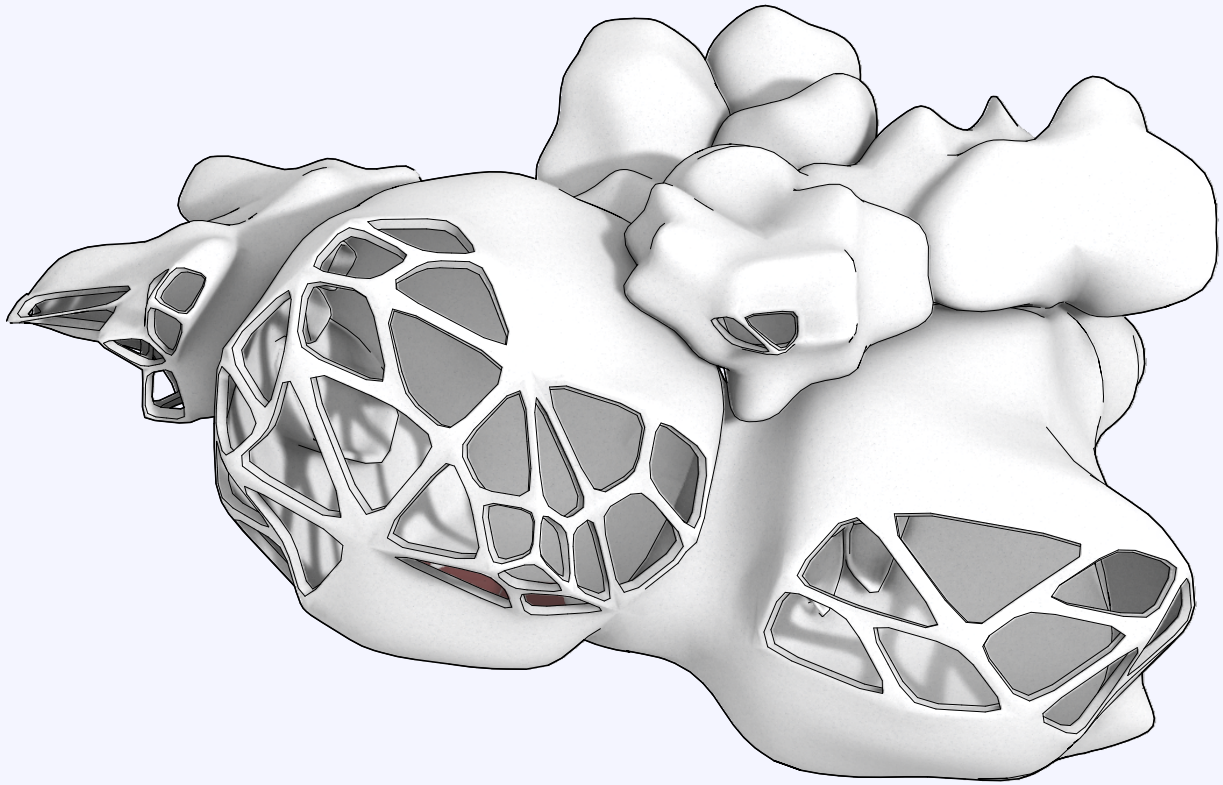


Generative spatial organization with differently sized apartment spaces.



Mass-customizible structural system.

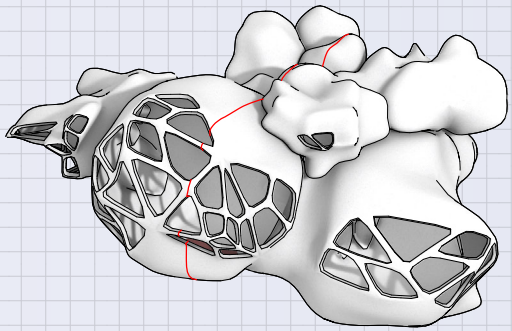
meso scale output



apartment stacking

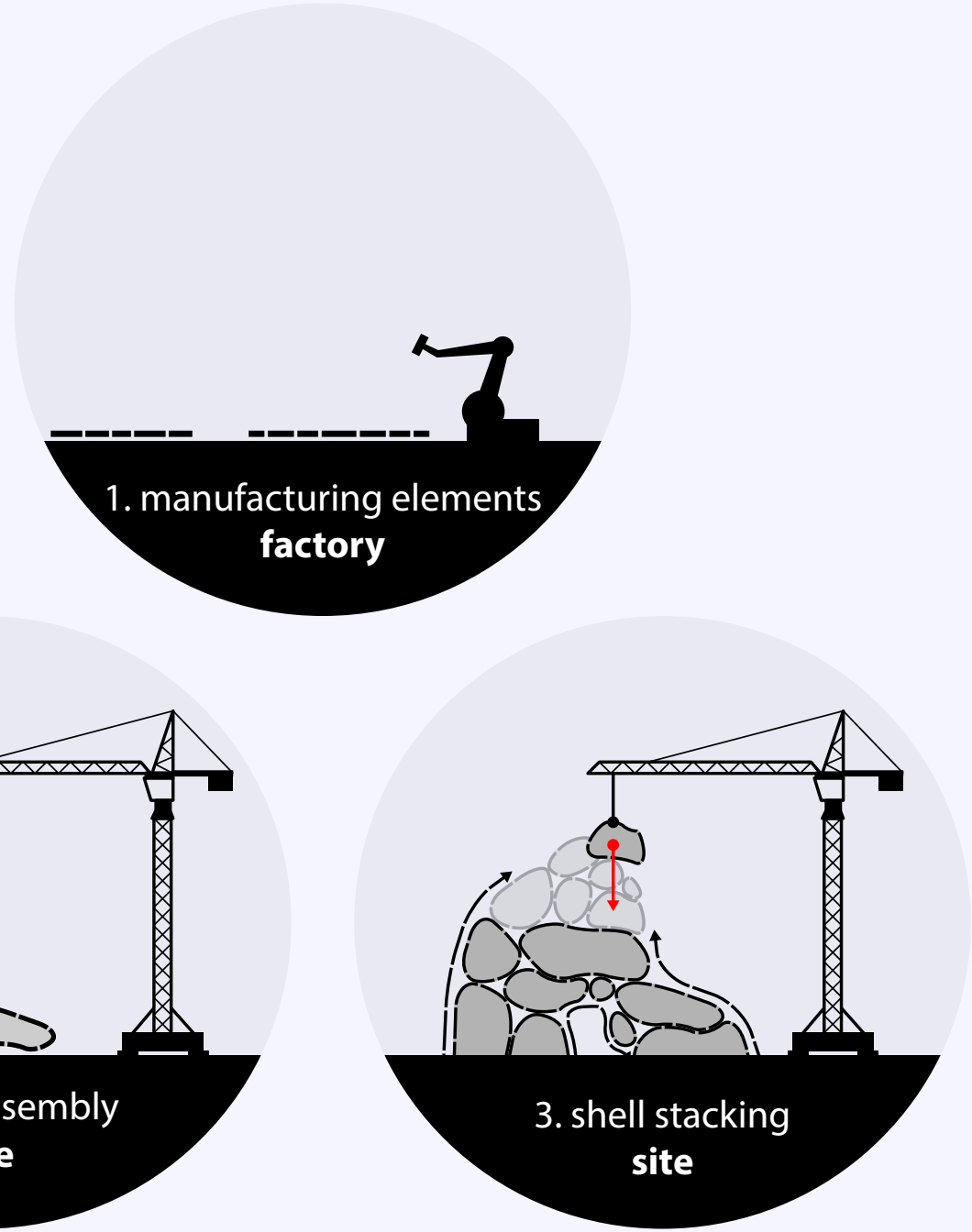


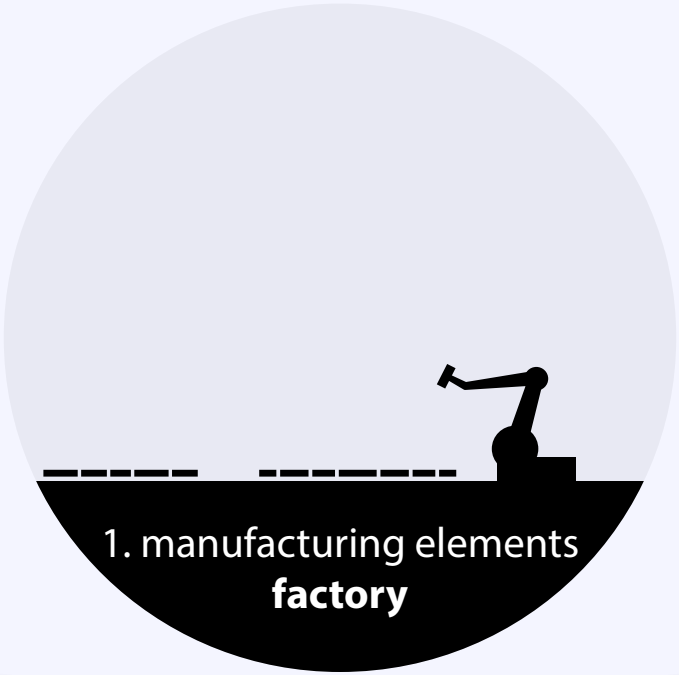
facade fragment
sound insulation

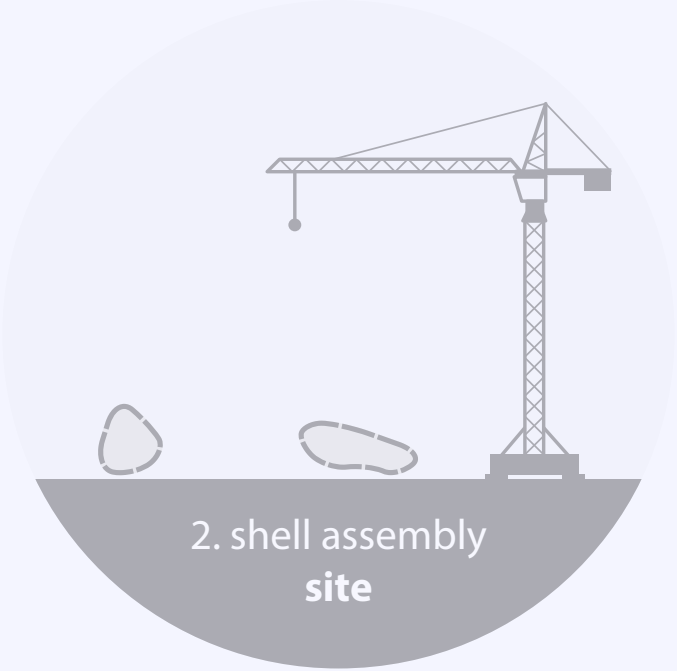


1000 mm

building process



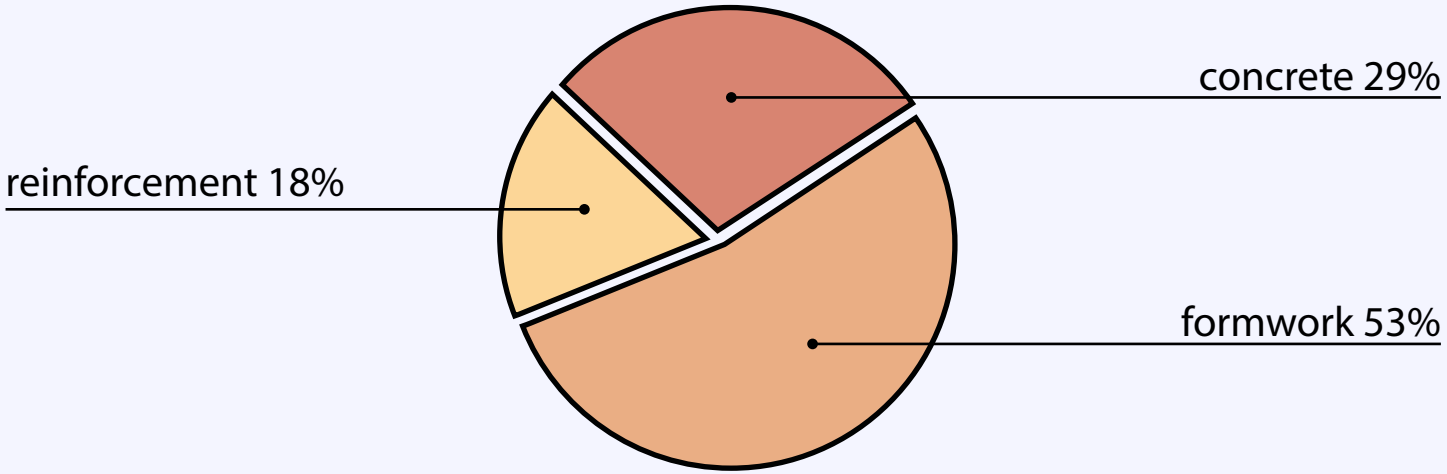

1. manufacturing elements
factory


2. shell assembly
site


3. shell stacking
site

additive vs. subtractive

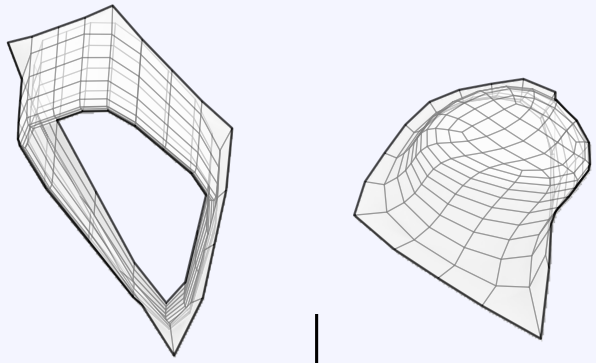
cost of formwork



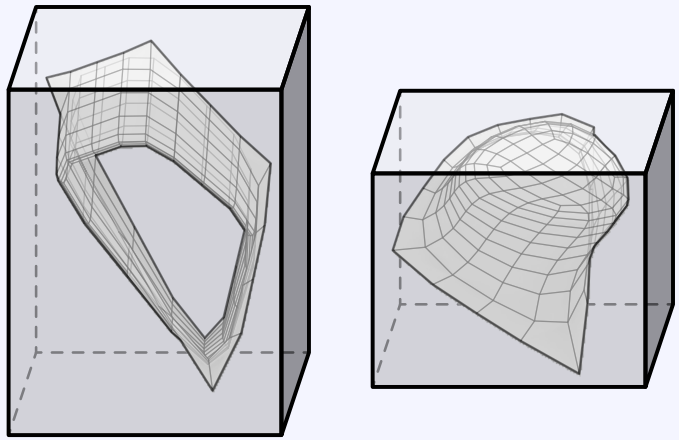
building cost of solid load bearing constructions.
H. Robert, "Think formwork-reduced cost," Structure Magazine, April, pp. 14–16, 2007.

additive vs. subtractive

geometry

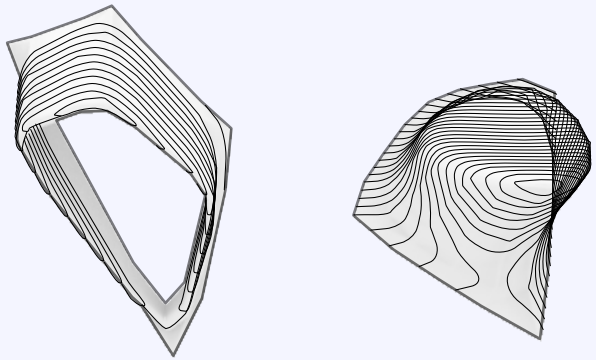


subtractive [casting]



excess material as formwork

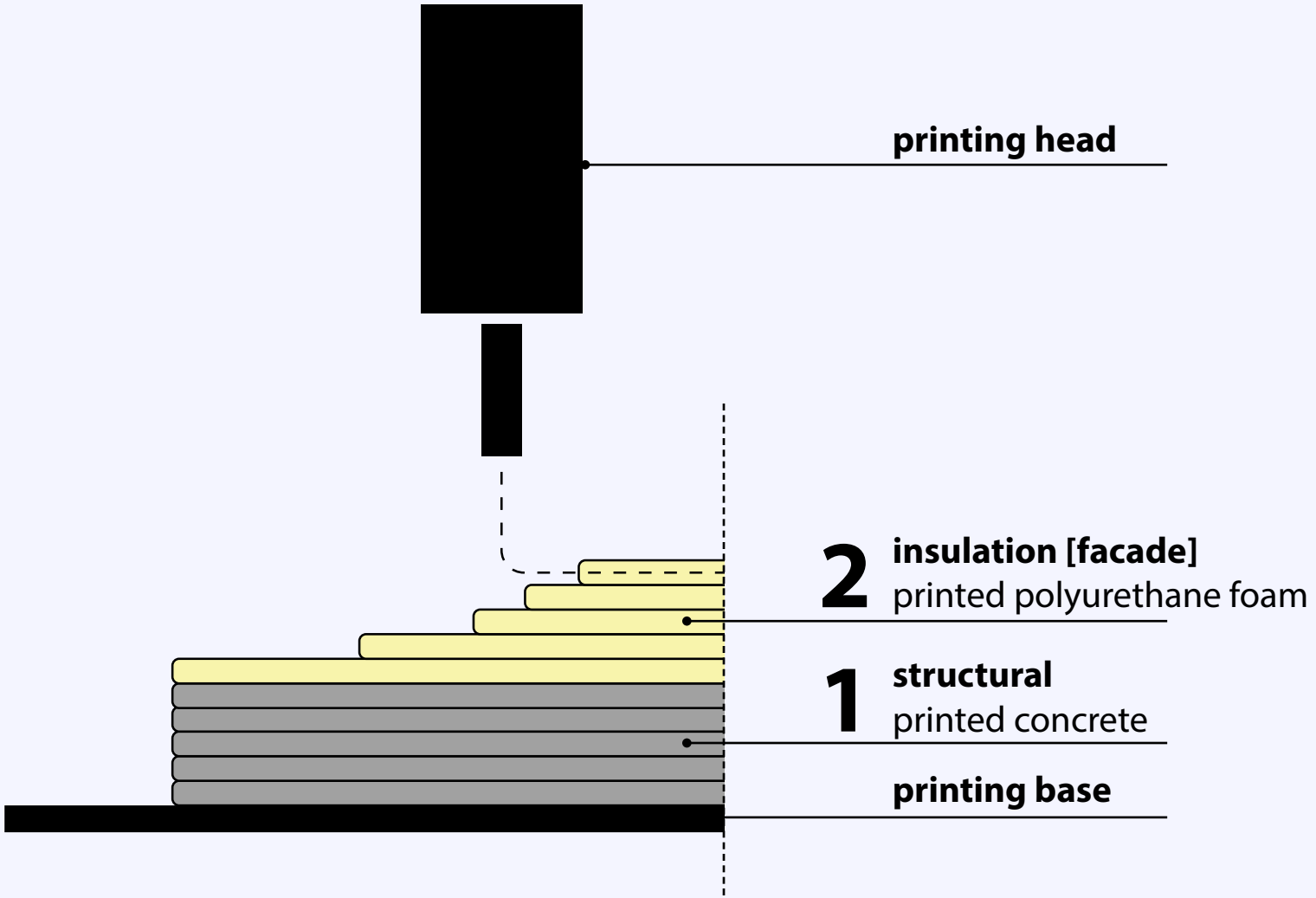
additive [3D printing]



only material where needed

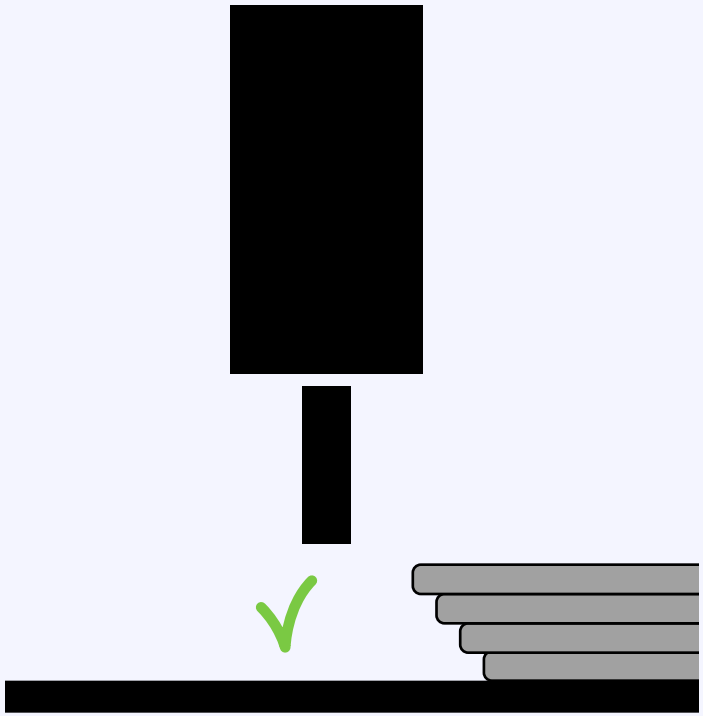
1. manufacturing elements

basic principle

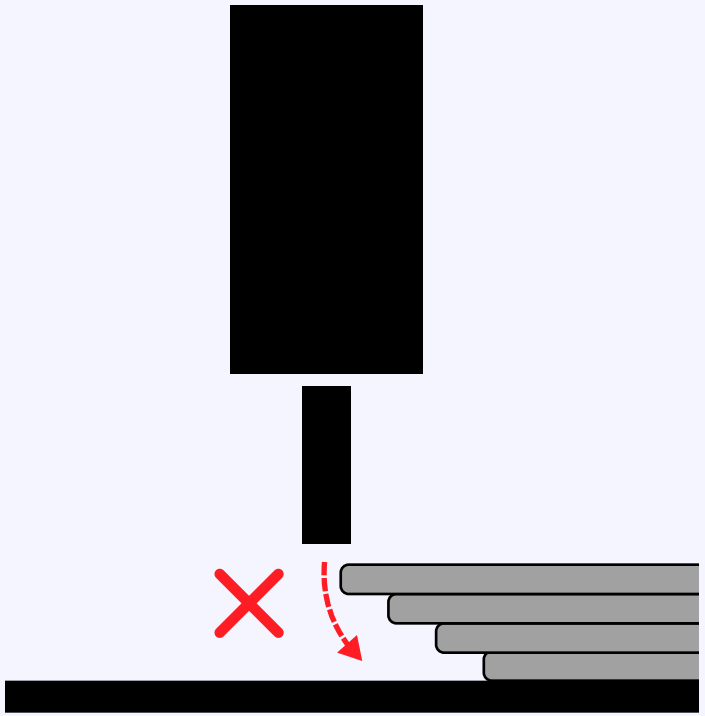


1. manufacturing elements

3D printing limitations



print layers within max. angle



print layers exceed max. angle
>> print collapse

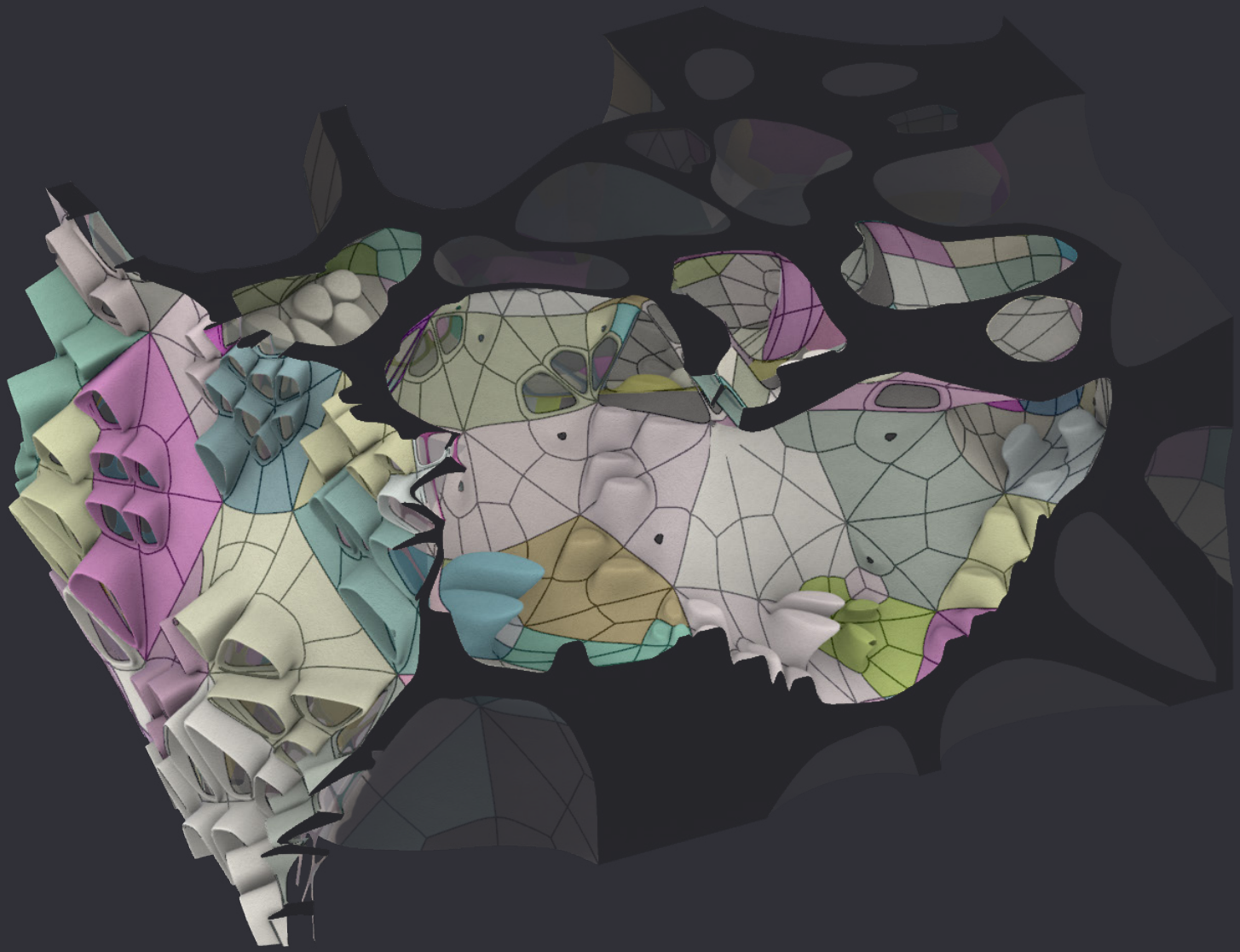
1. manufacturing elements

mesh faces



1. manufacturing elements

define elements based on size & planarity

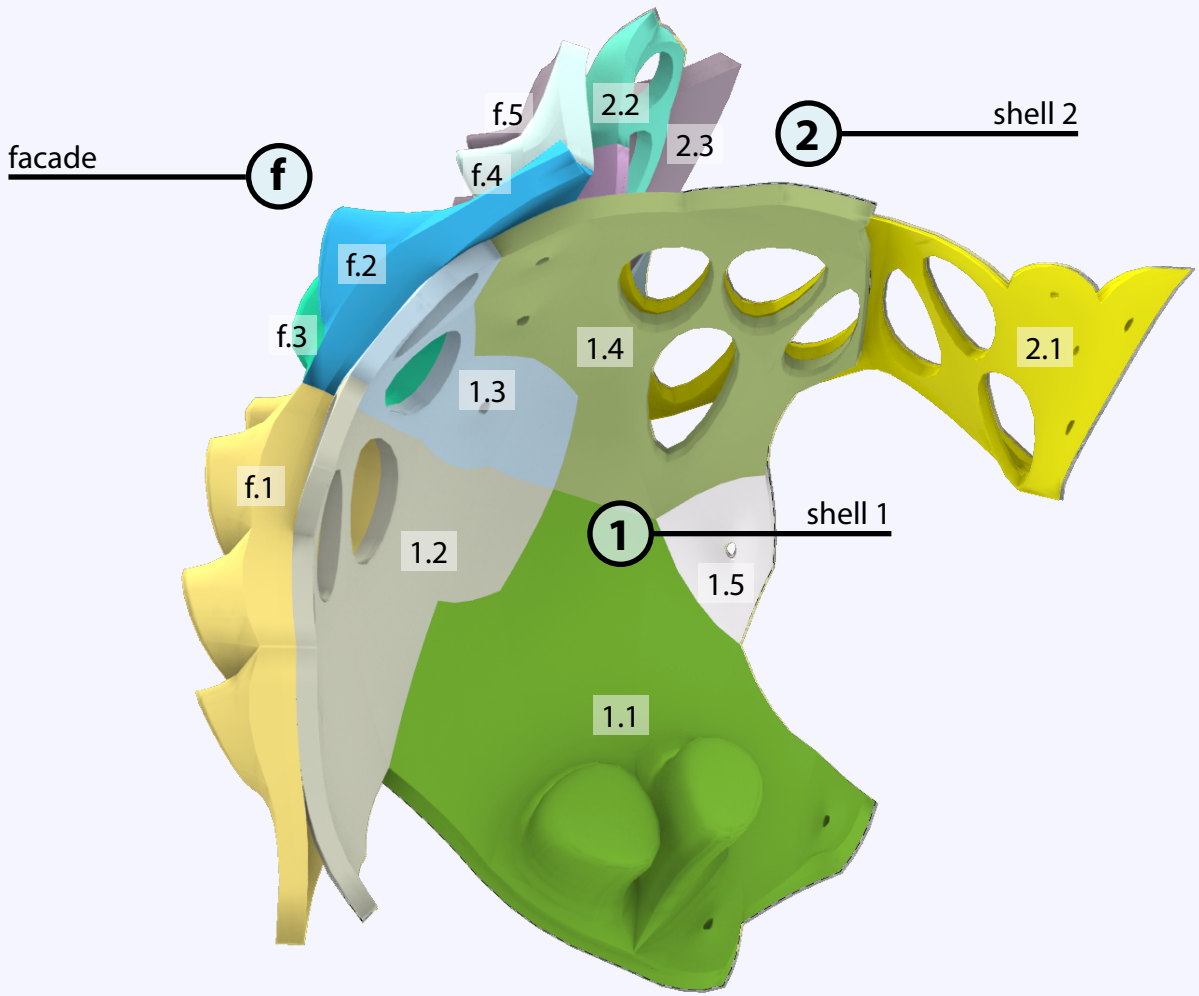


1. manufacturing elements
detail selection



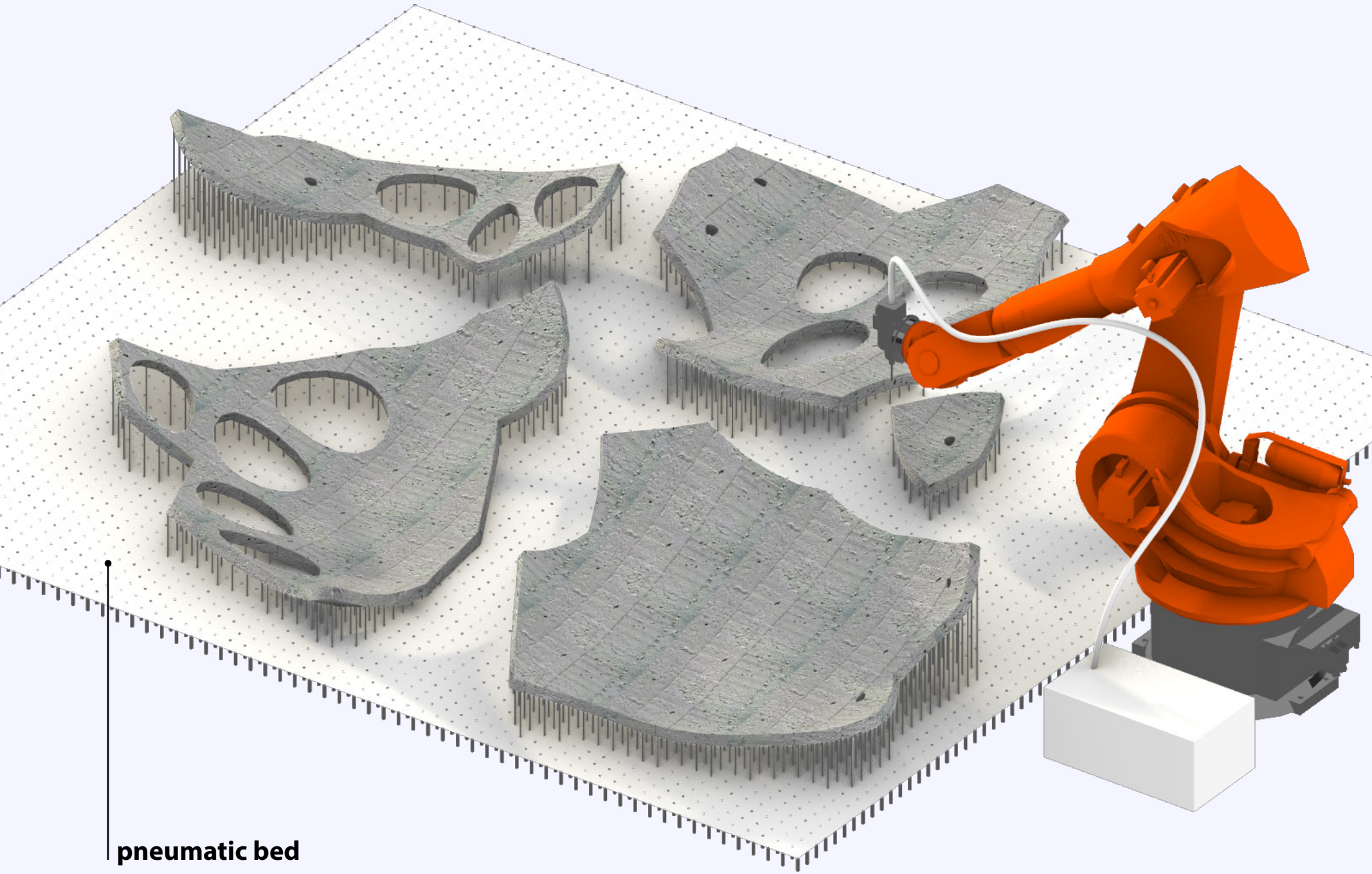
1. manufacturing elements

digital model output - detail



1. manufacturing elements

structural concrete



1. manufacturing elements

printing on double curved surface

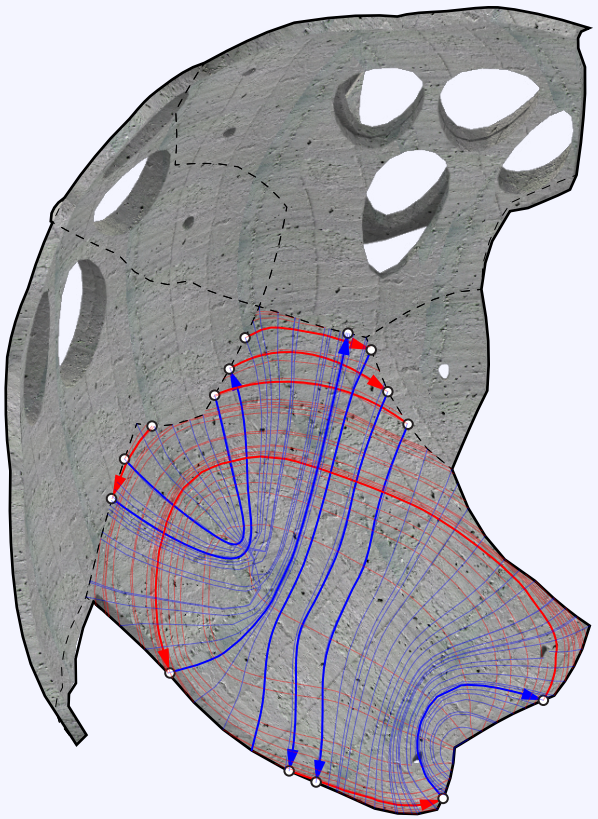


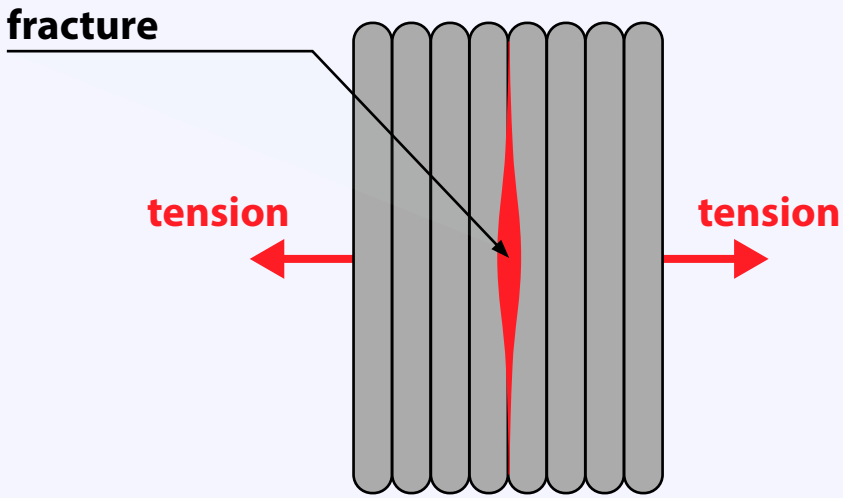
https://www.4tu.nl/bouw/en/LHP2016/Double%20Curved%203D%20Concrete%20Printing/



1. manufacturing elements

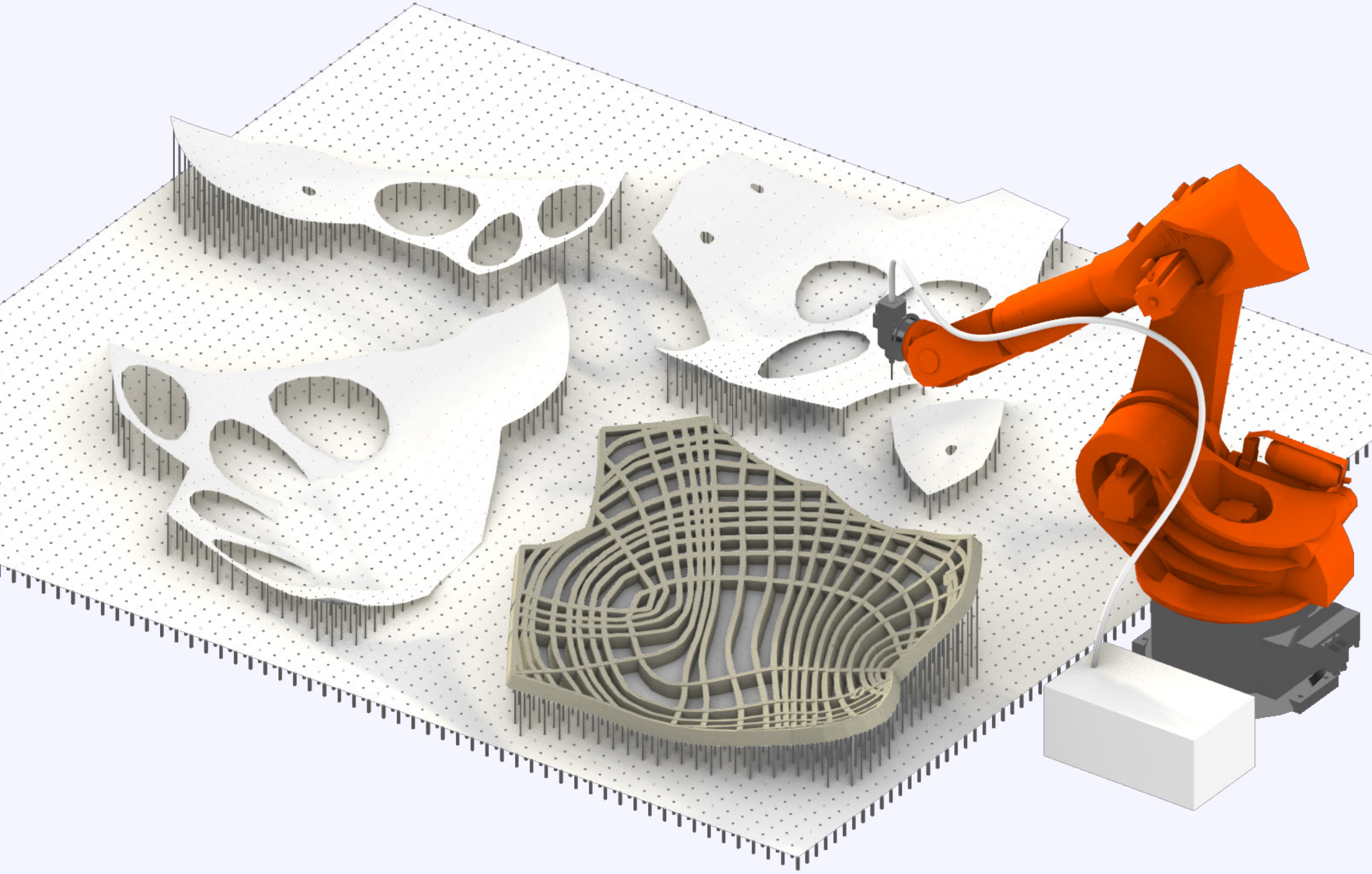
printing paths according to stress lines to reduce fractures





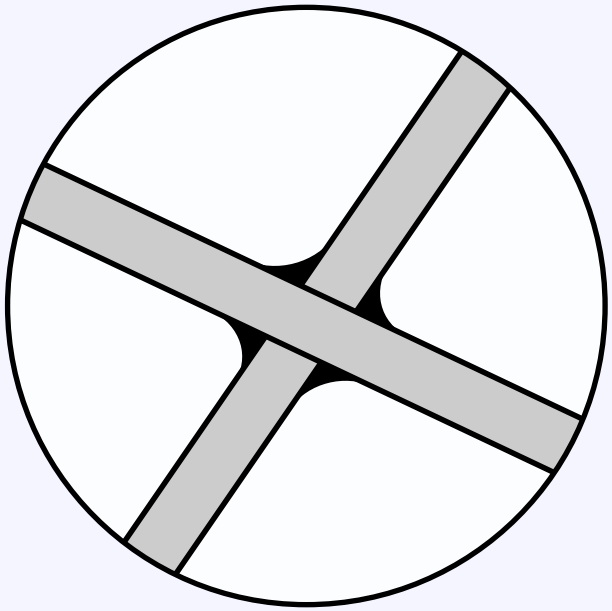
1. manufacturing elements

printing stress lines

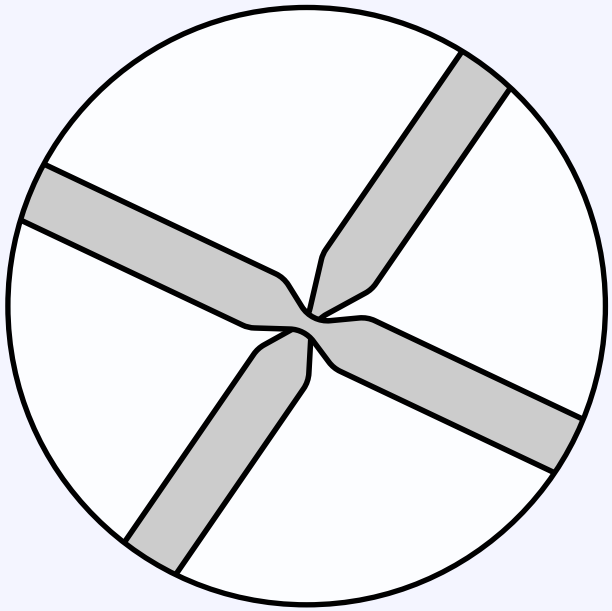


1. manufacturing elements

overlapping printing paths



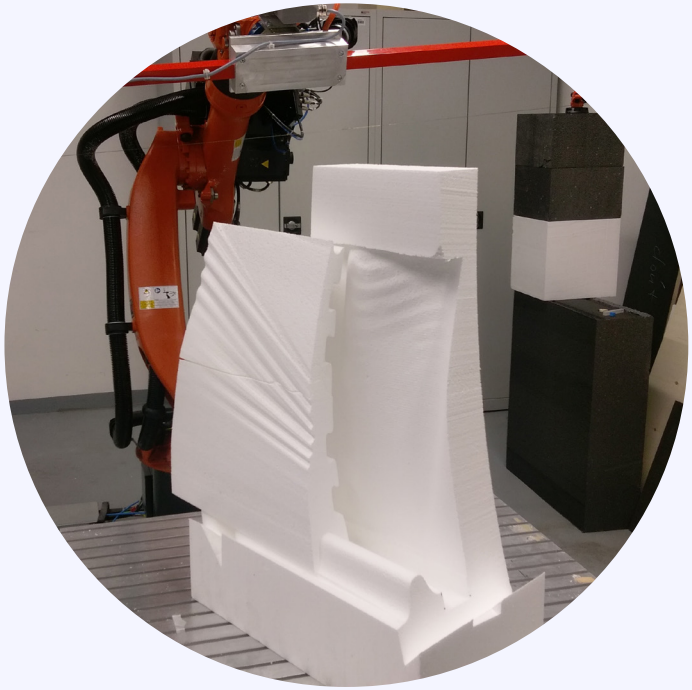
material accumulation

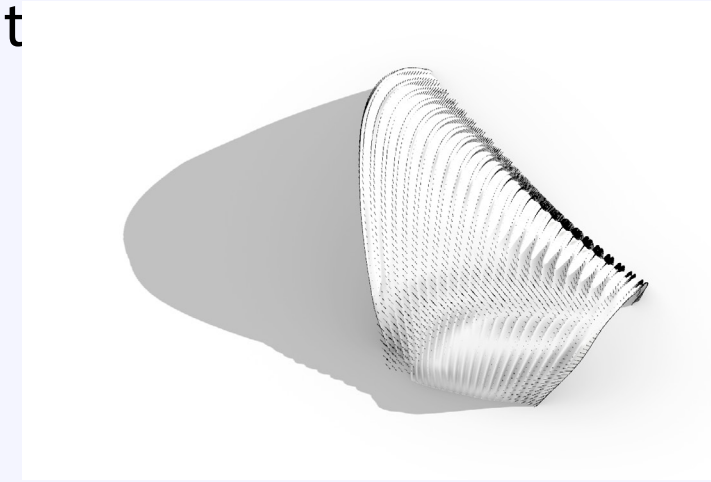


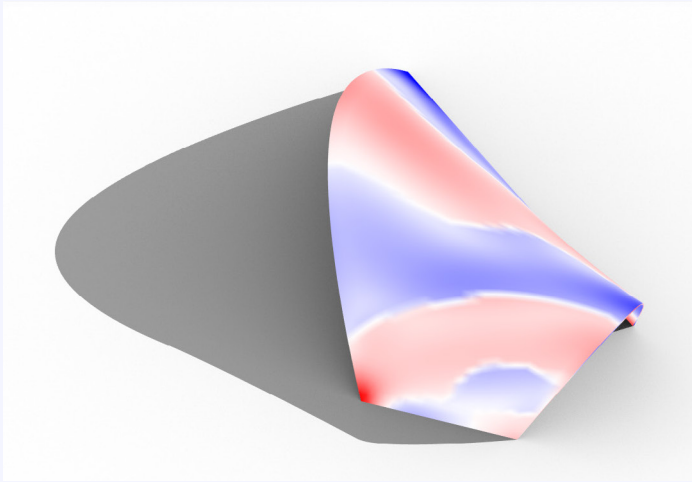
<u>no</u> material accumulation by reducing print volume on intersections

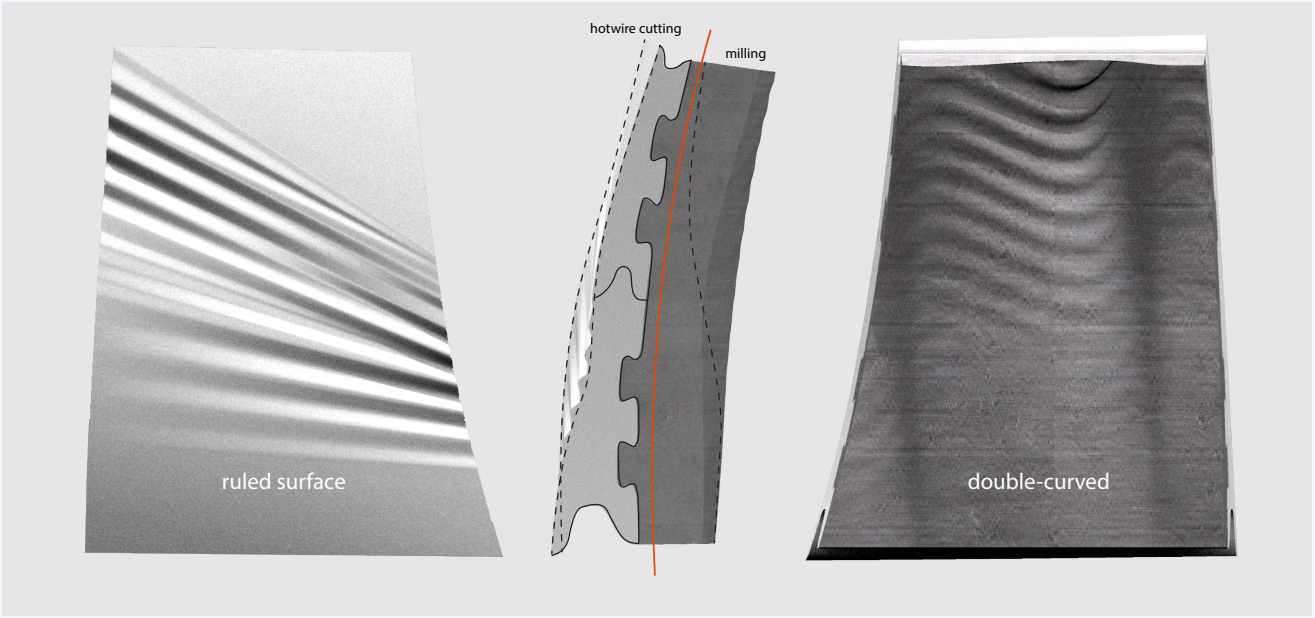
1. manufacturing element

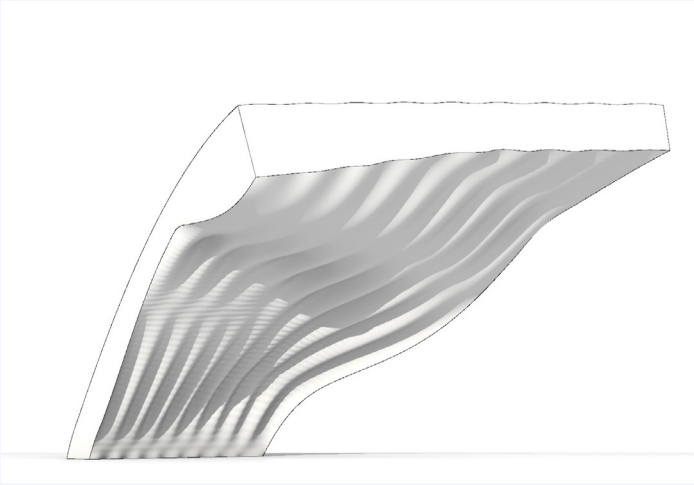
stress-based variable thickness





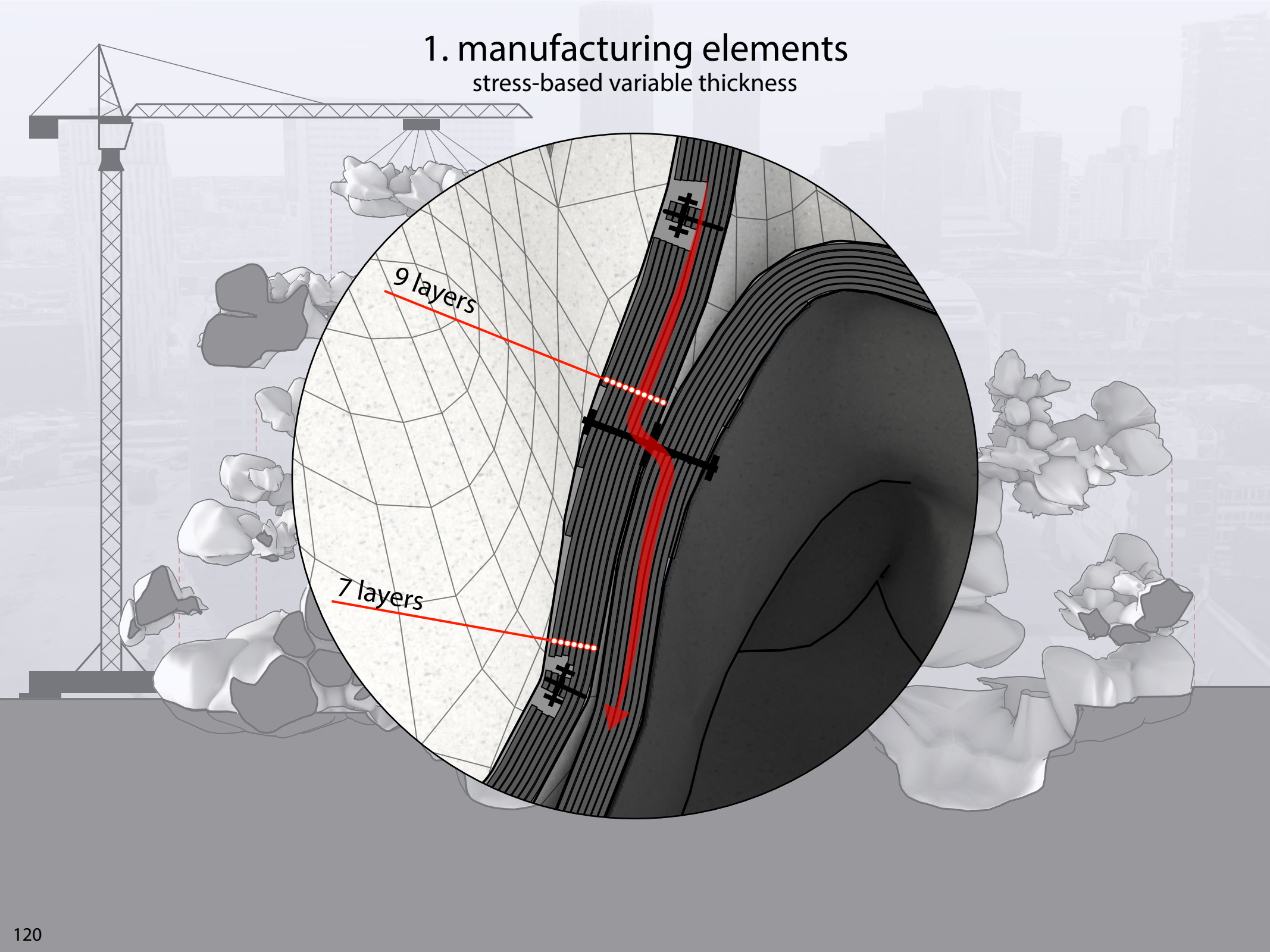






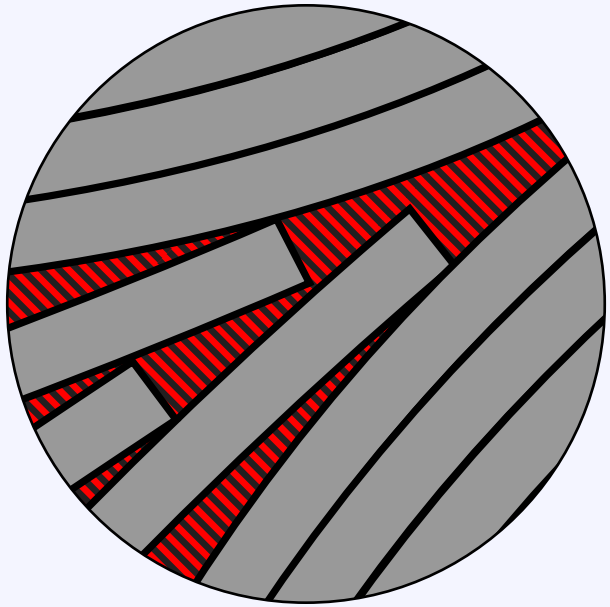
1. manufacturing elements

stress-based variable thickness



1. manufacturing elements

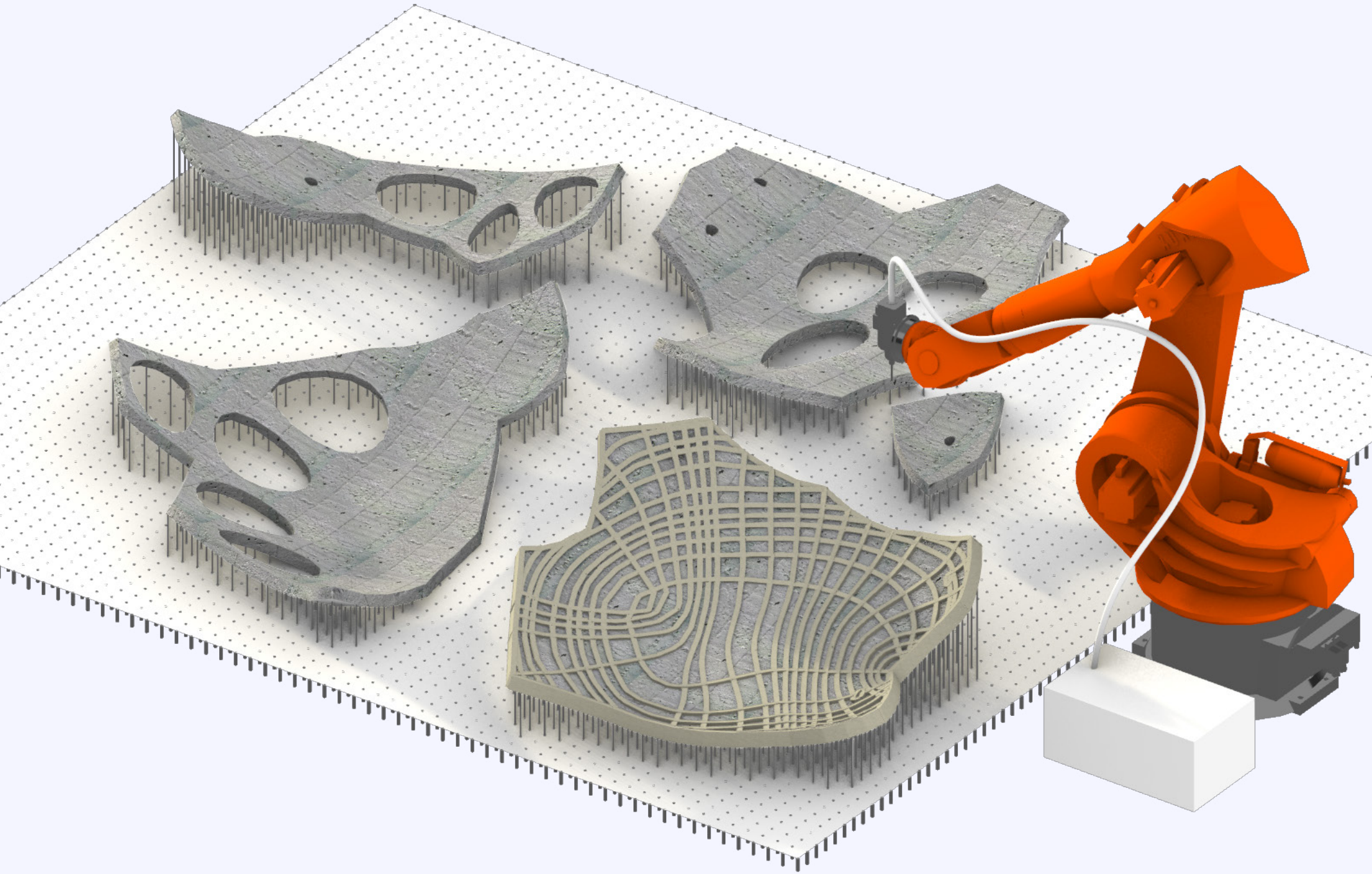
casting



printing-only causes gaps

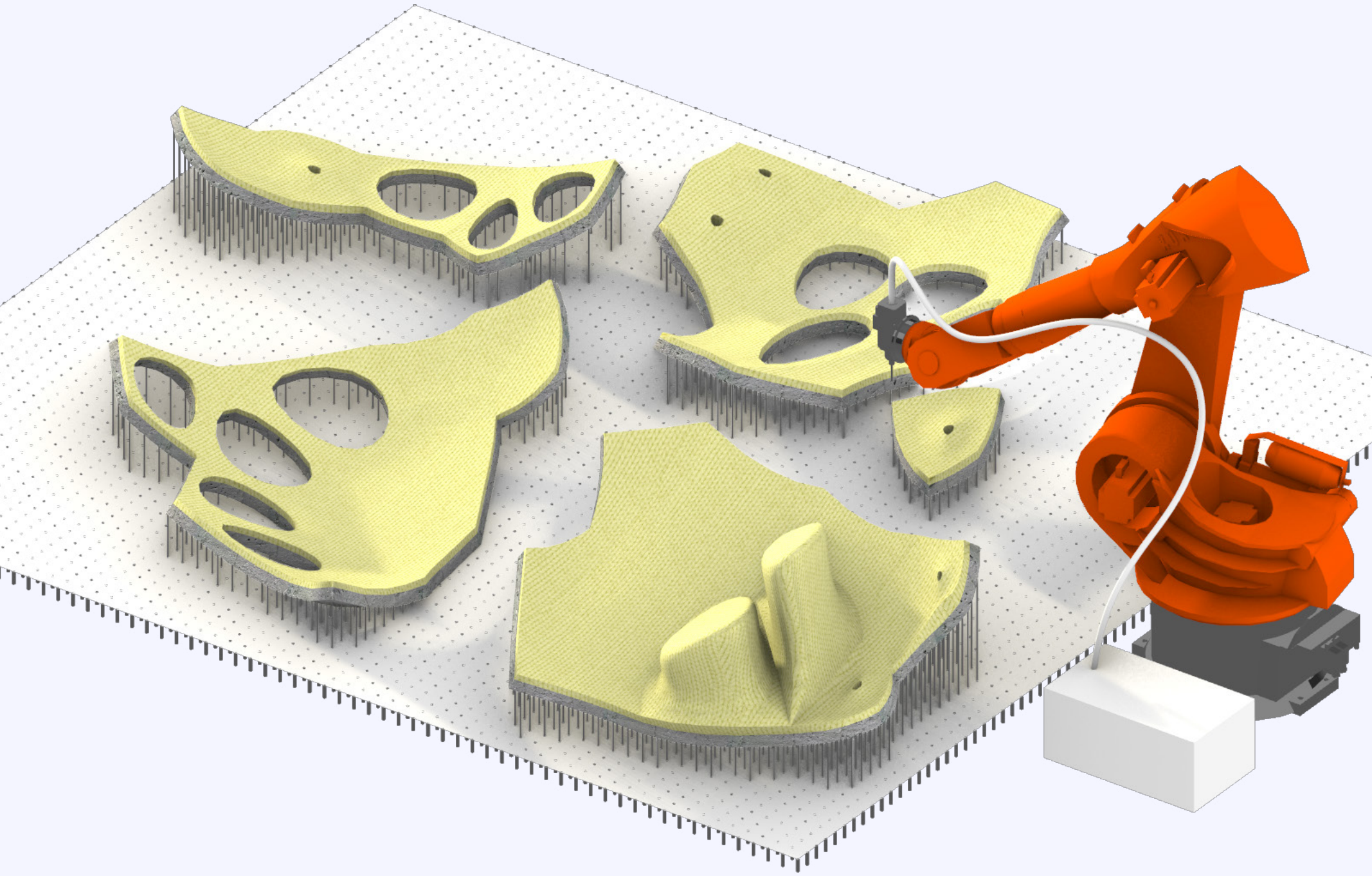
1. manufacturing elements

casting



1. manufacturing elements

polyurethane foam [facade]

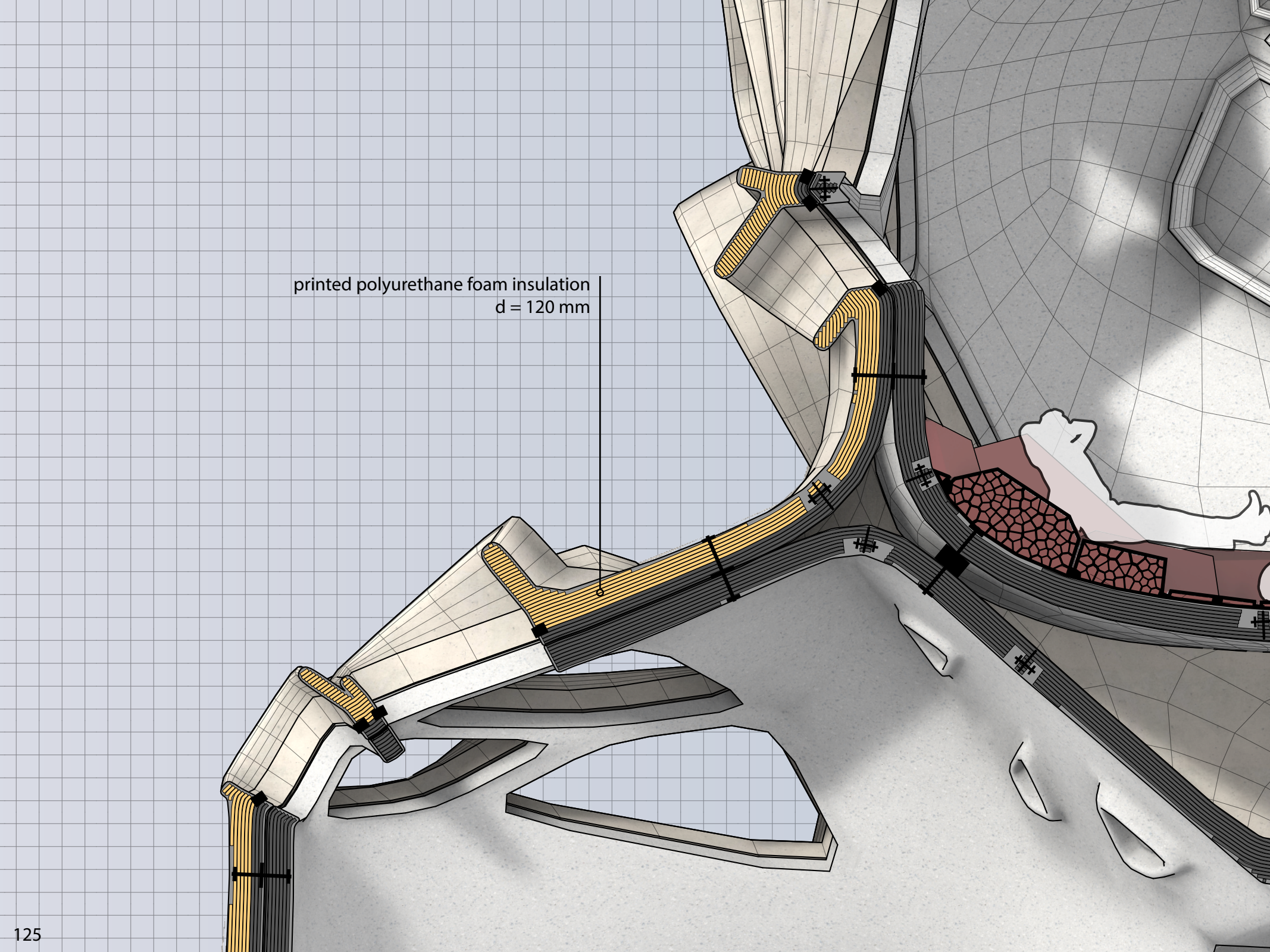


1. manufacturing elements
polyurethane foam printing





formicom
https://www.fomicom.com/en/applications/3d-printing/


printed polyurethane foam insulation
d = 120 mm

1. manufacturing elements

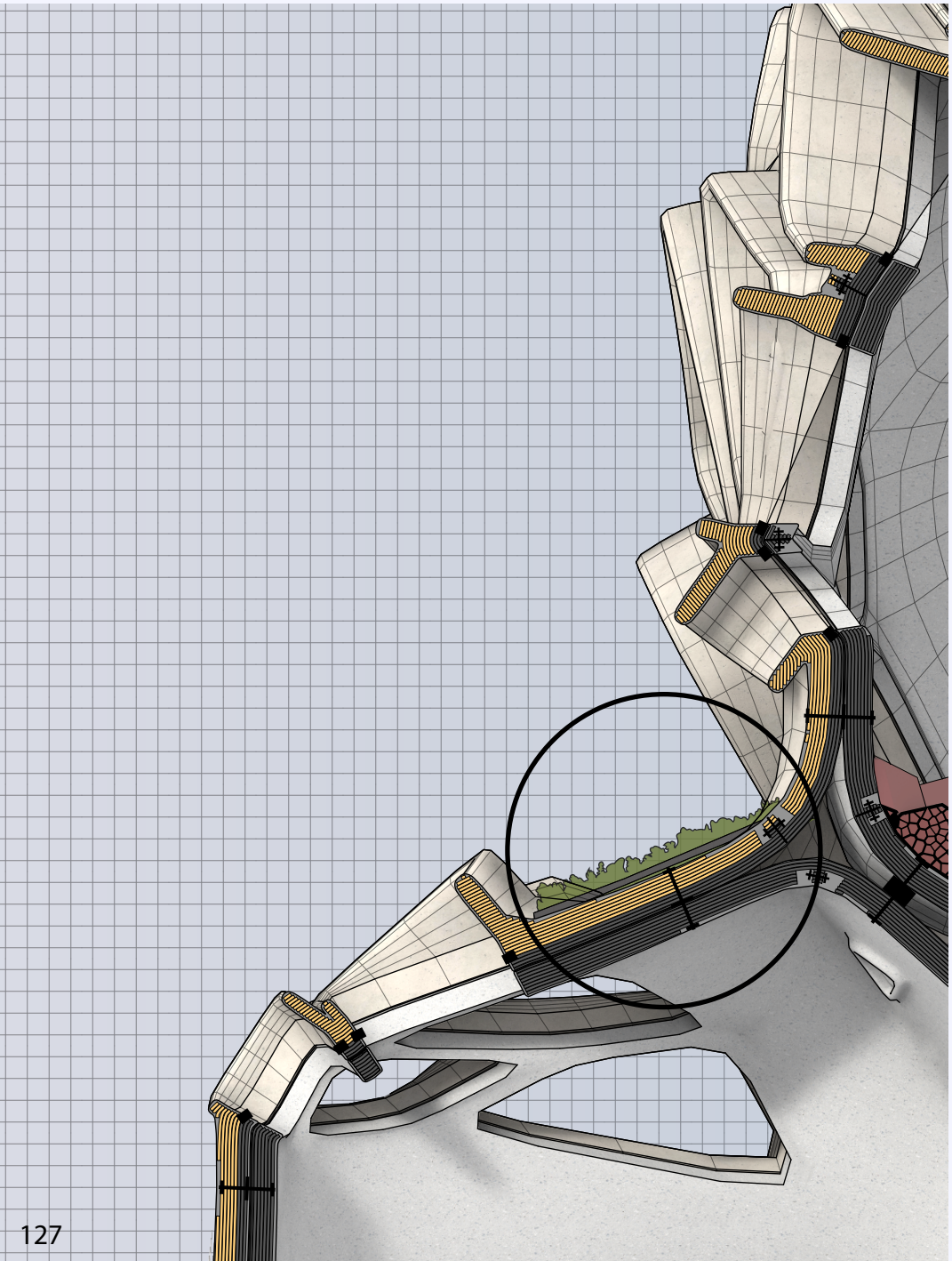


concrete recycling (source: Rutte Groep)

alternative: insulation by printing morphology

1. manufacturing elements

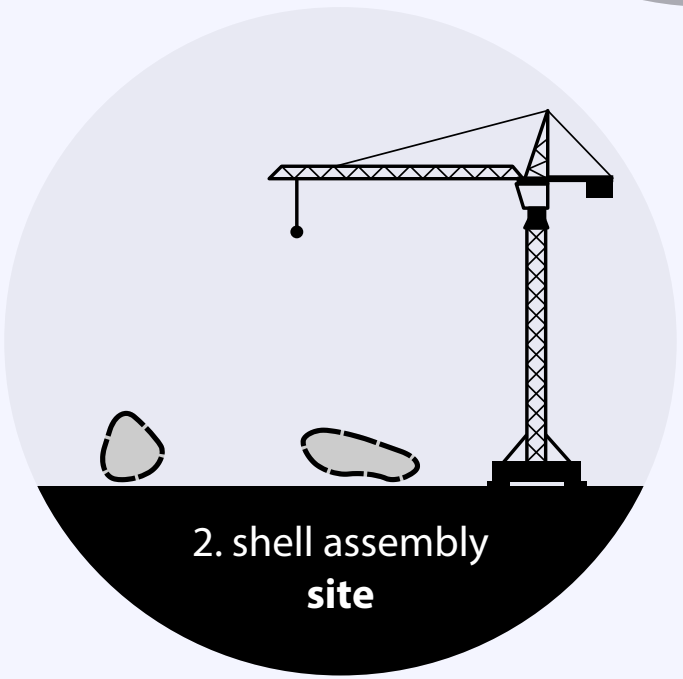
using printing surface quality for vegetation

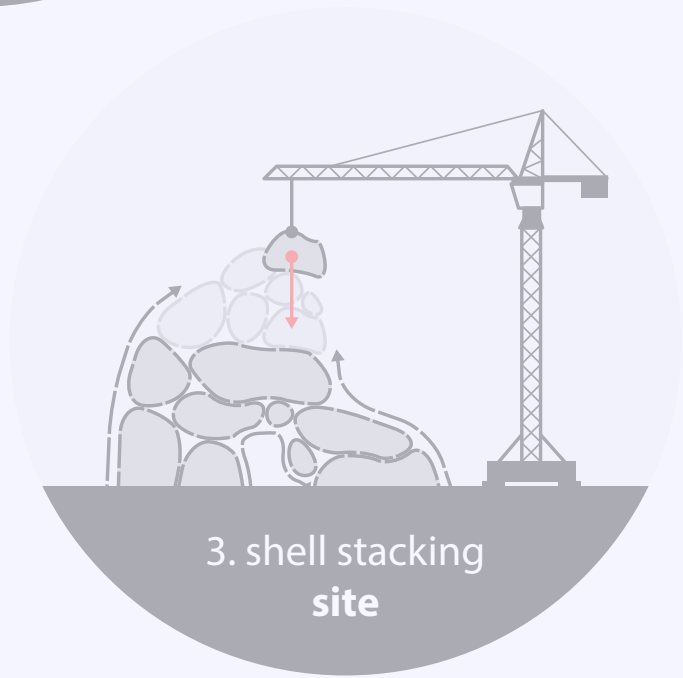




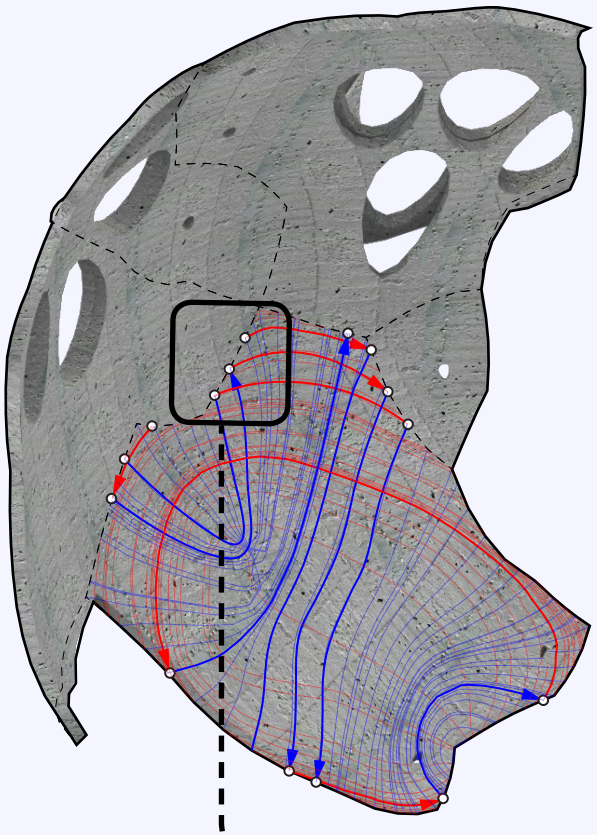
Megoru Sky Garden
Tokyo

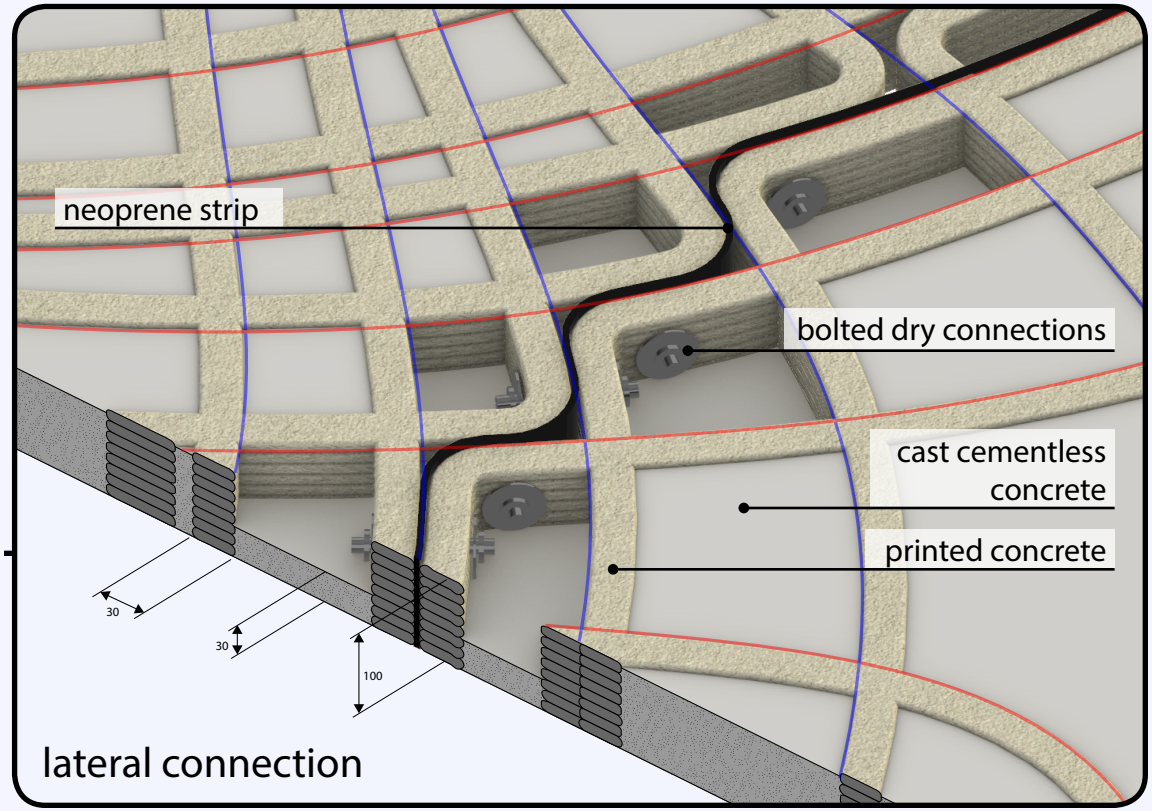

1. manufacturing elements
factory


2. shell assembly
site


3. shell stacking
site

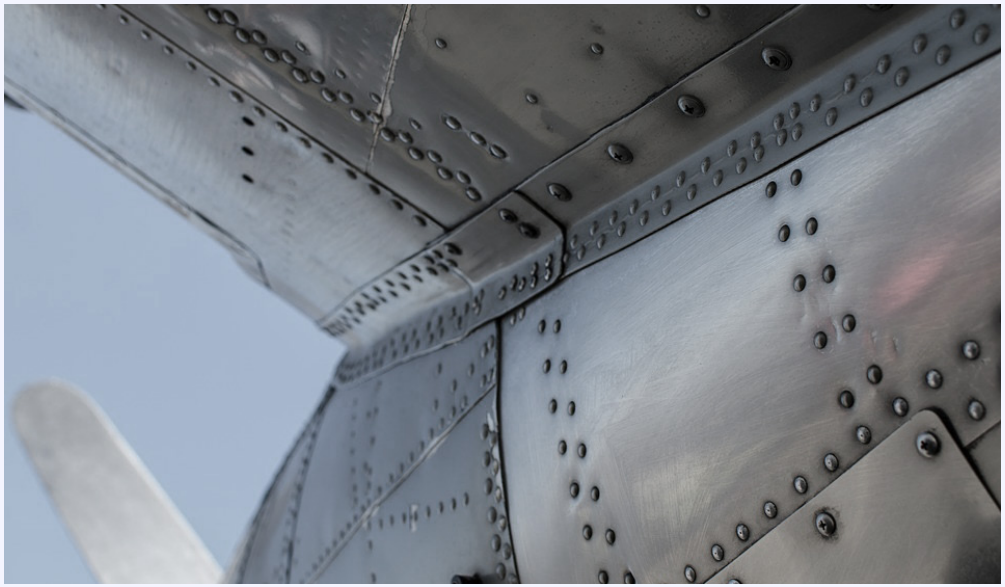
2. shell assembly
lateral connections

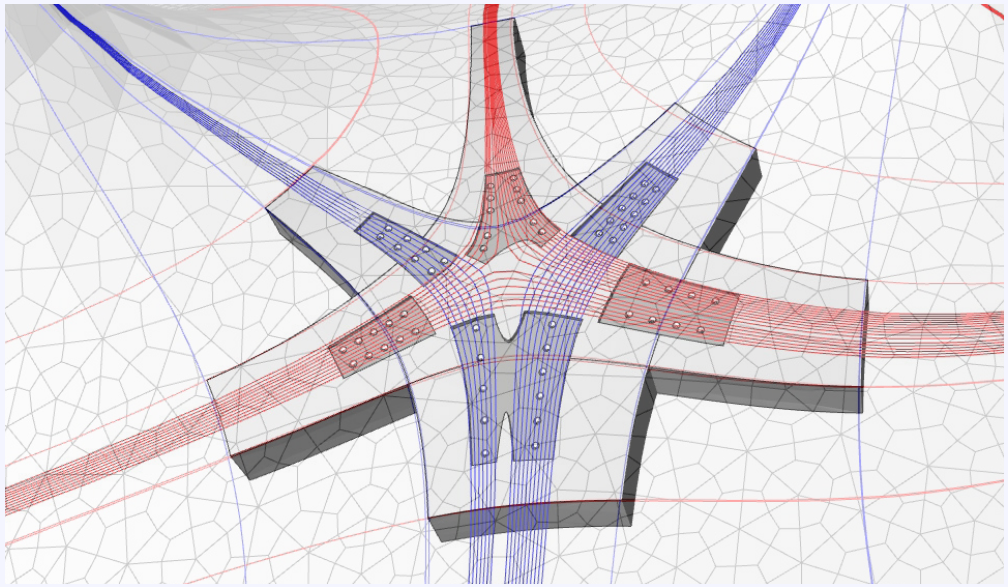




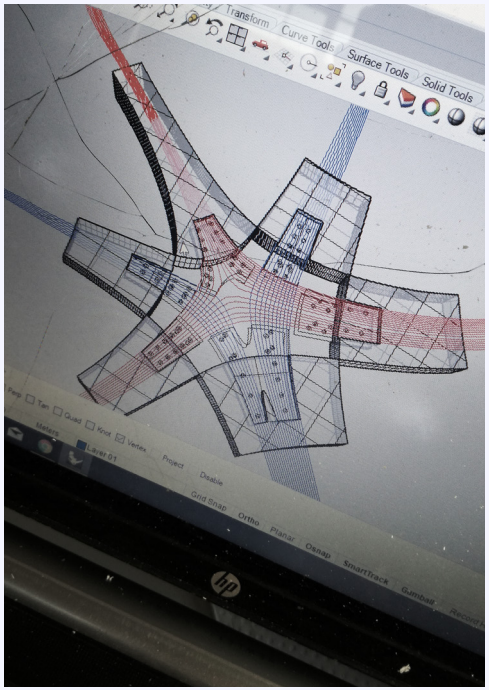
1. manufacturing elements

workshop 3: stress line-based structural connections





toolpath modeling



robotic milling



assembly

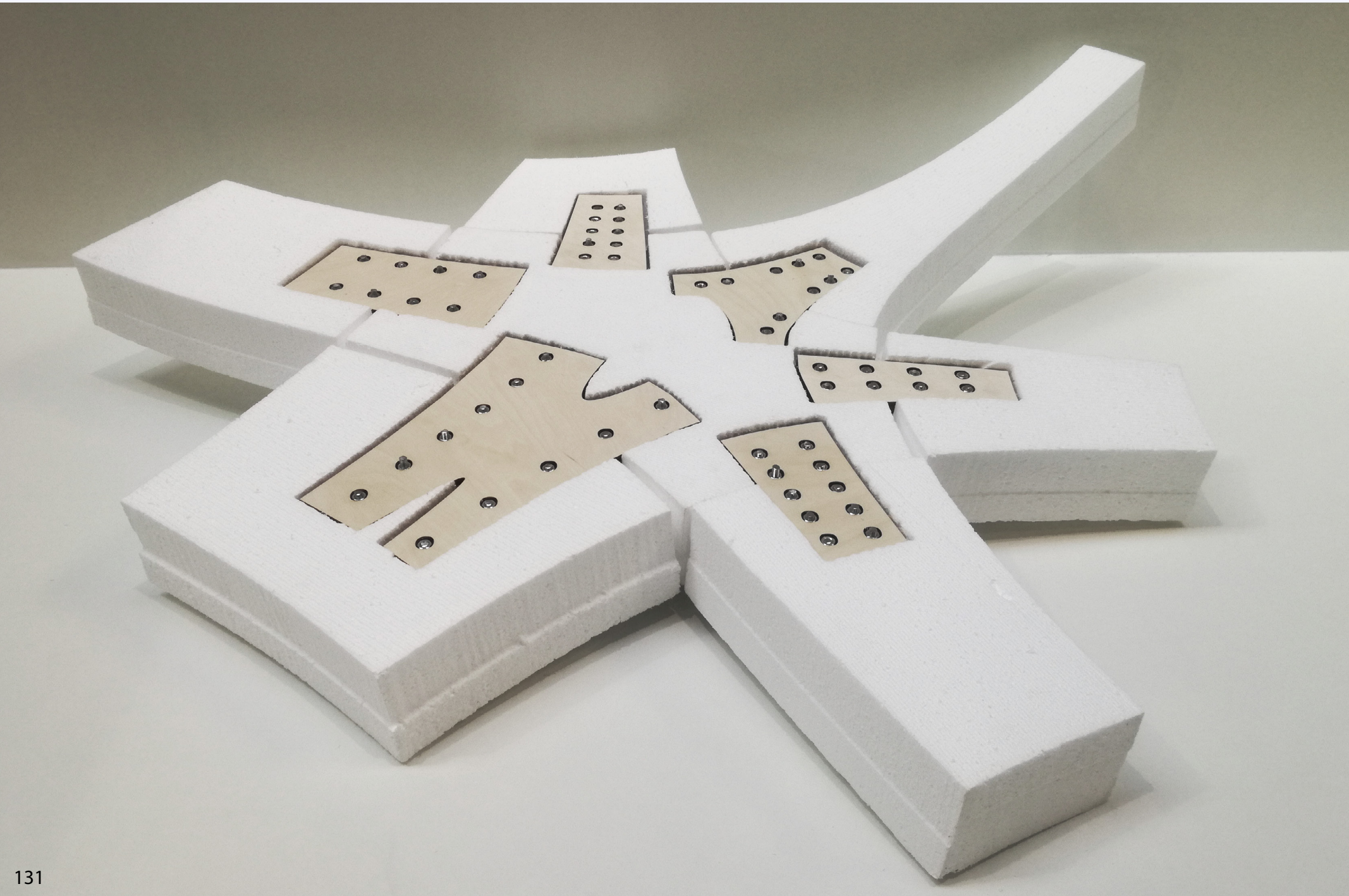


assembly detail

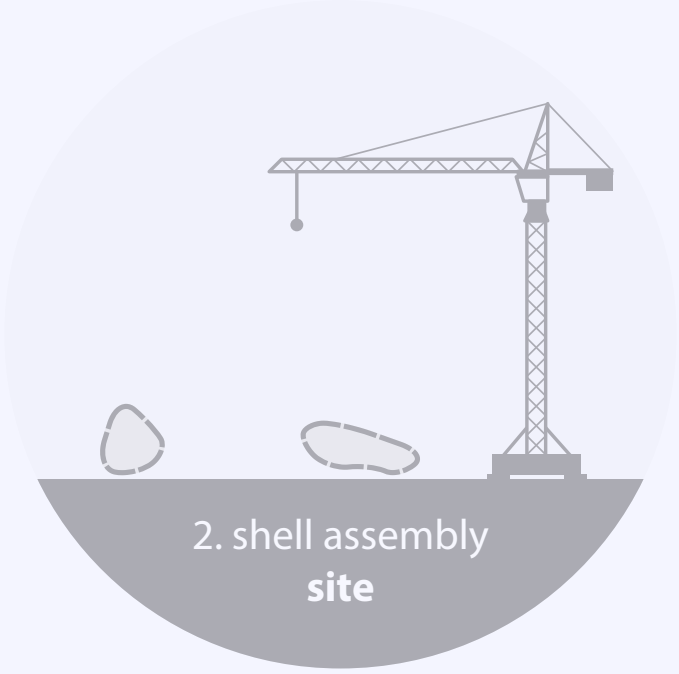


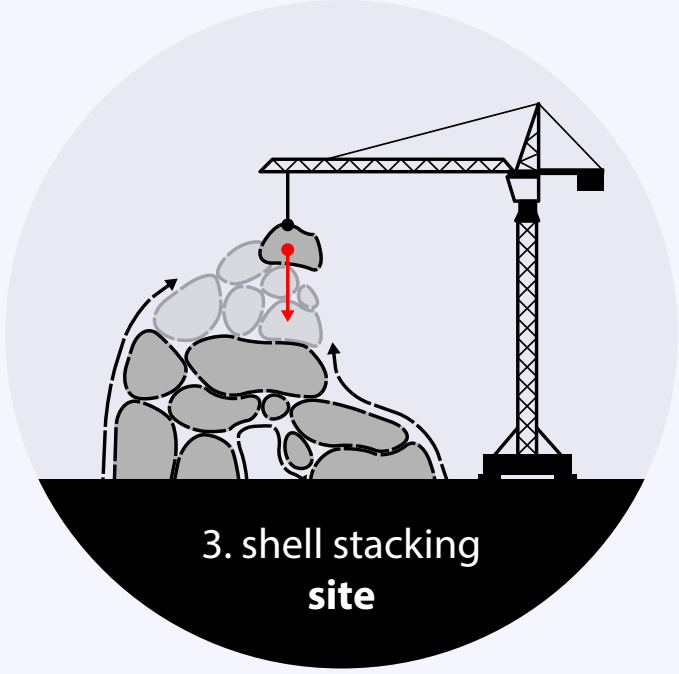
1. manufacturing elements

workshop 3 final prototype

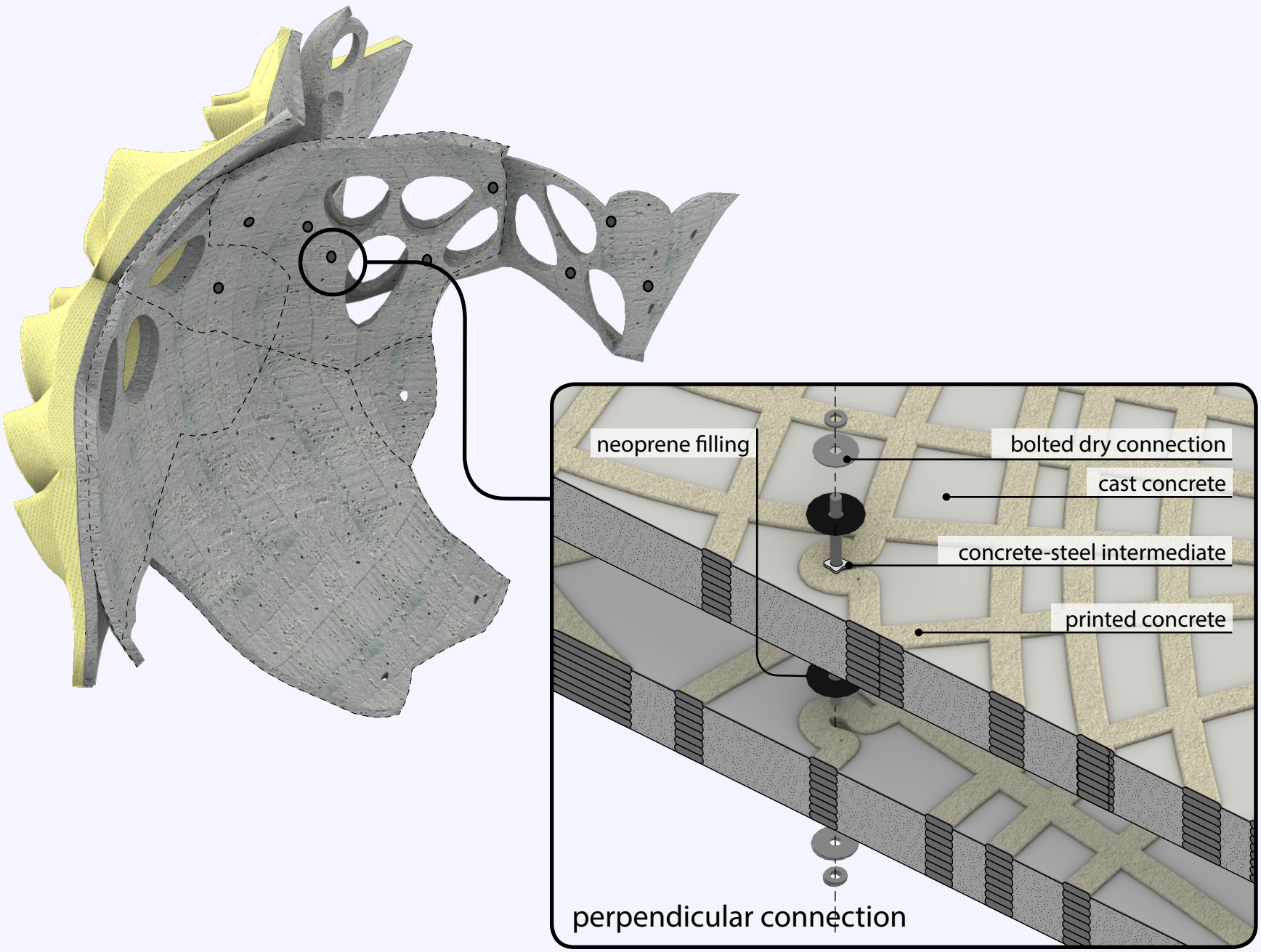



1. manufacturing elements
factory


2. shell assembly
site

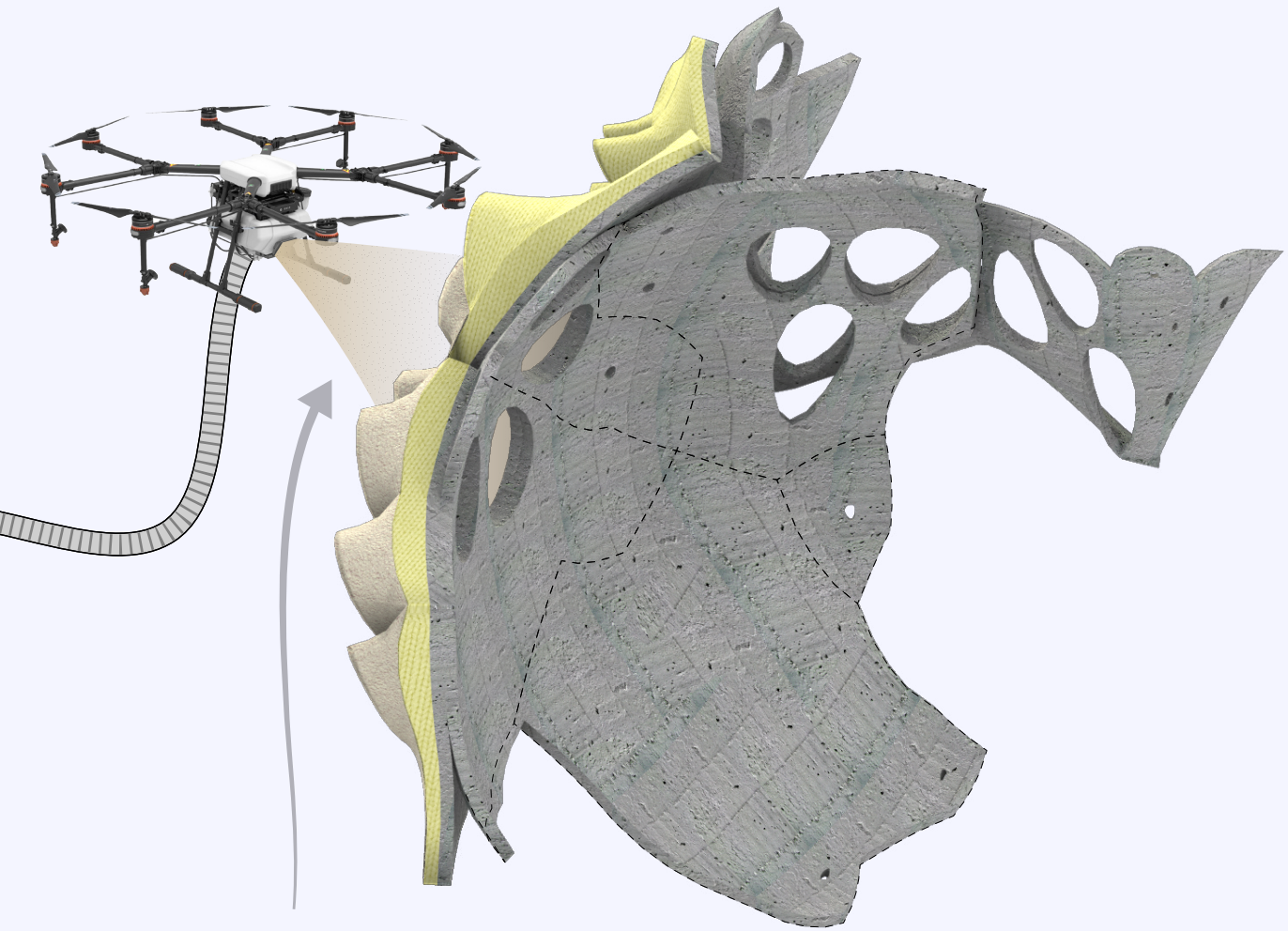

3. shell stacking
site

3. shell stacking

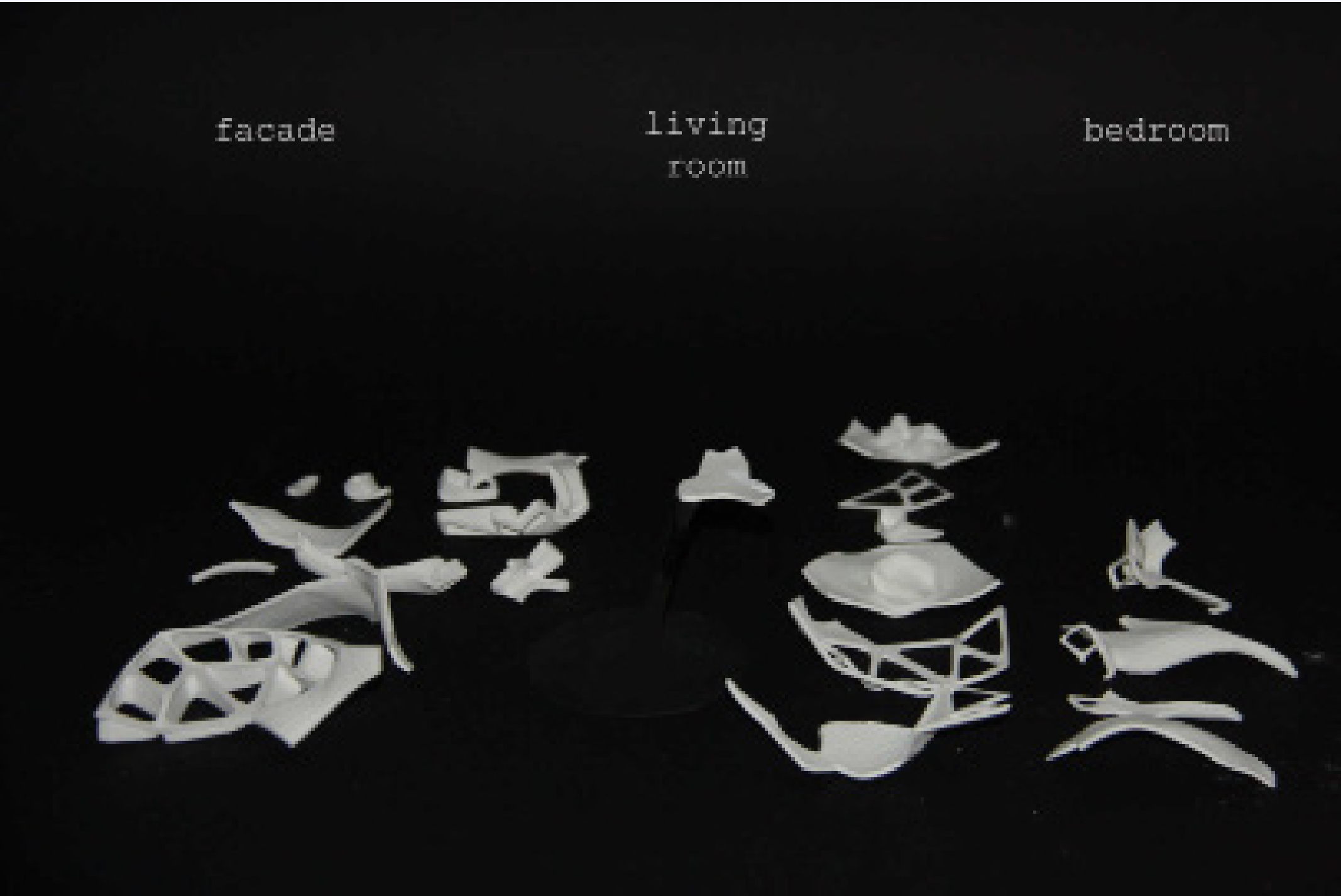


3. shell stacking

finishing [human-robot collaboration]



fabrication



connection with existing technologies



Voorbij Prefab - automated gantry system for mold placement



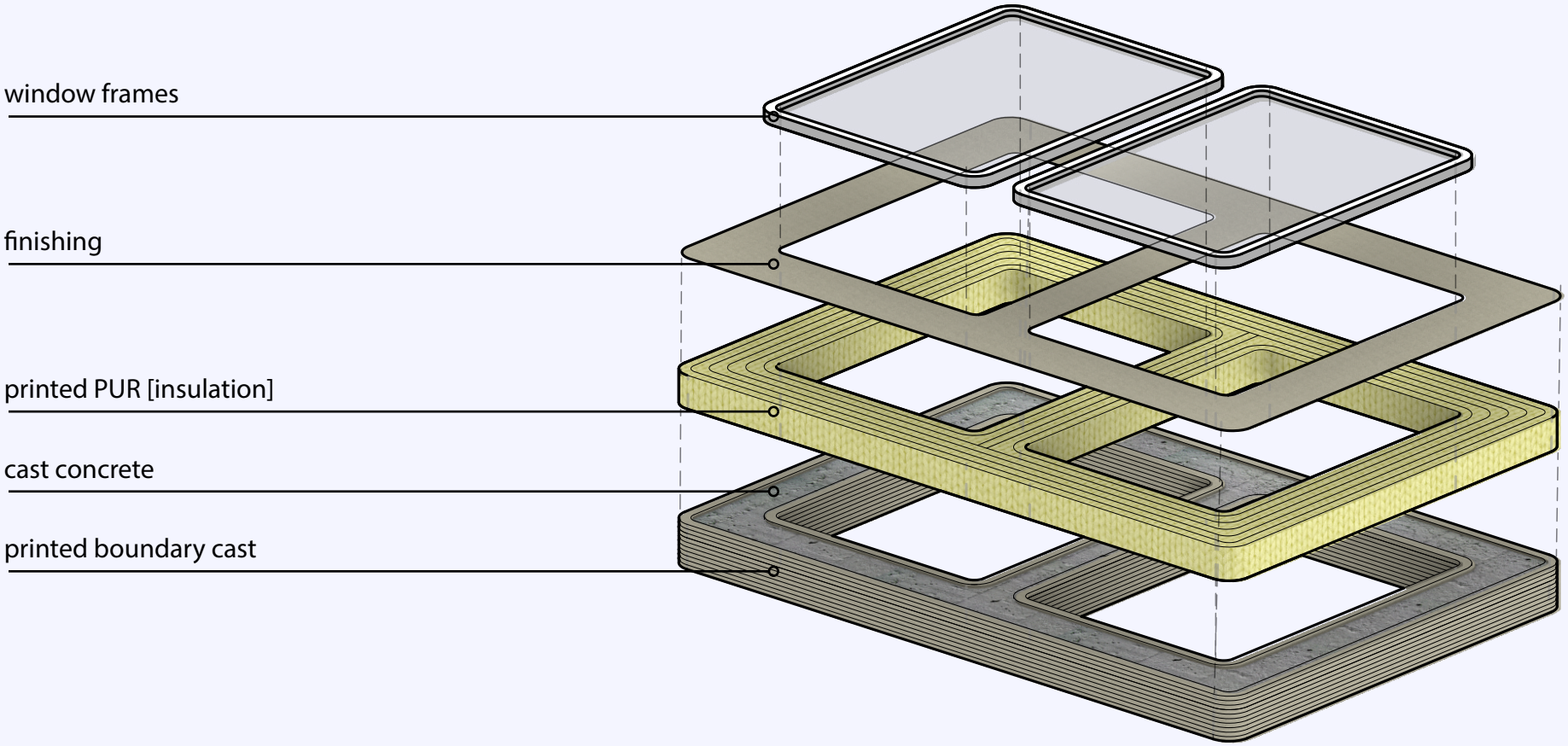
Polyurethane insulation - extrusion of thermal insulative material



concrete filling - scattered extrusion

planar building system

- increased design freedom
- decreased labour cost
- integrating facade functionalities in one manufacturing process (structural, shading, thermal insulation, windows)



densification designs



irresponsible uses of space

1. spatial organization

2. building volume

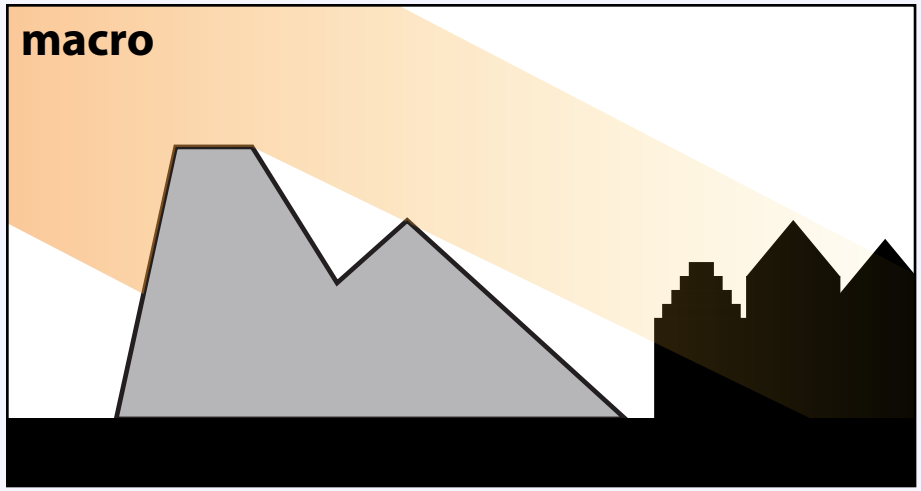
3. (public + private) green space

design assignment

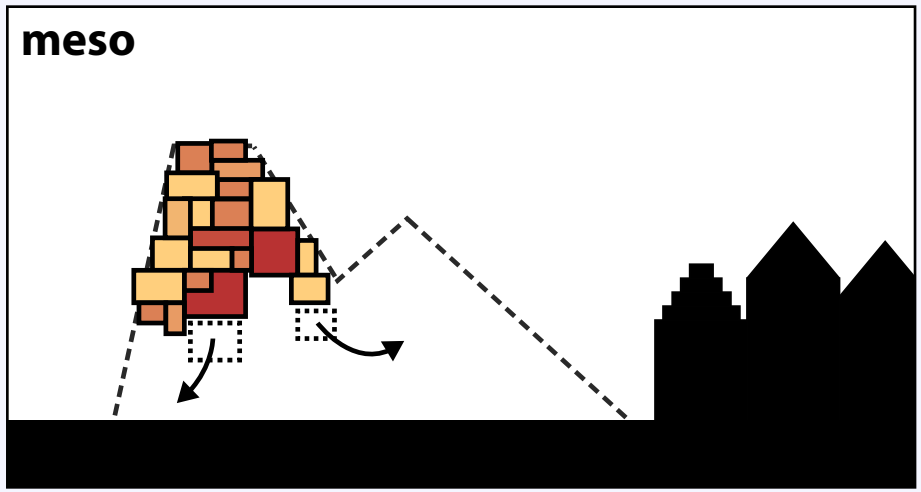
macro

meso

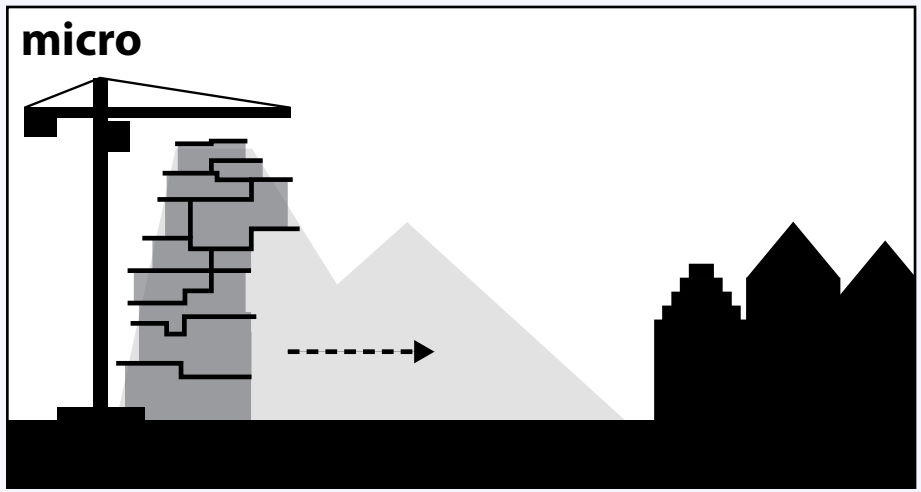
micro



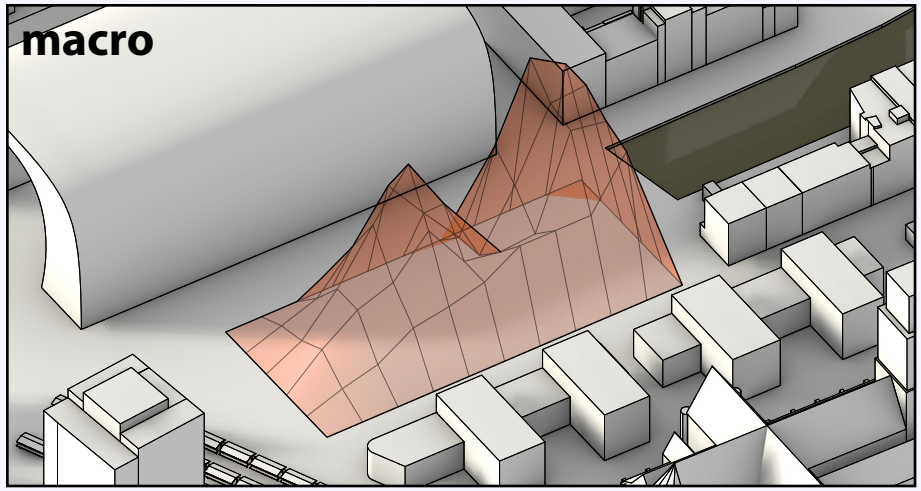
Bounding volume based on solar access of adjacent buildings/public spaces.



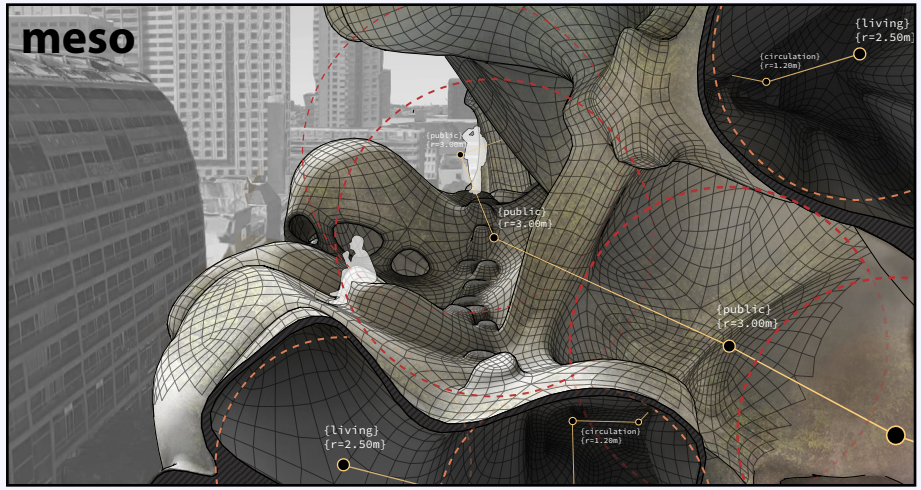
Generative spatial organization with differently sized apartment spaces.



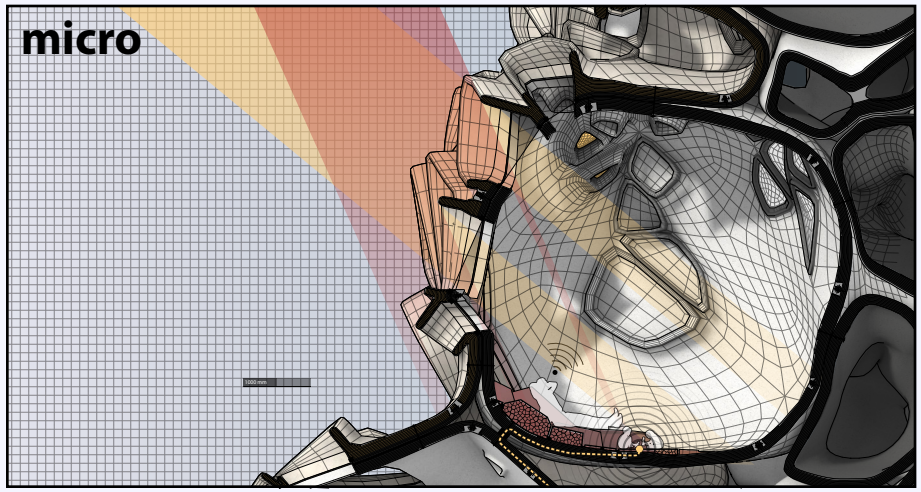
Mass-customizible structural system.



Bounding volume based on solar access of adjacent buildings/public spaces.



Generative spatial organization with differently sized apartment spaces.



Mass-customizible structural system.