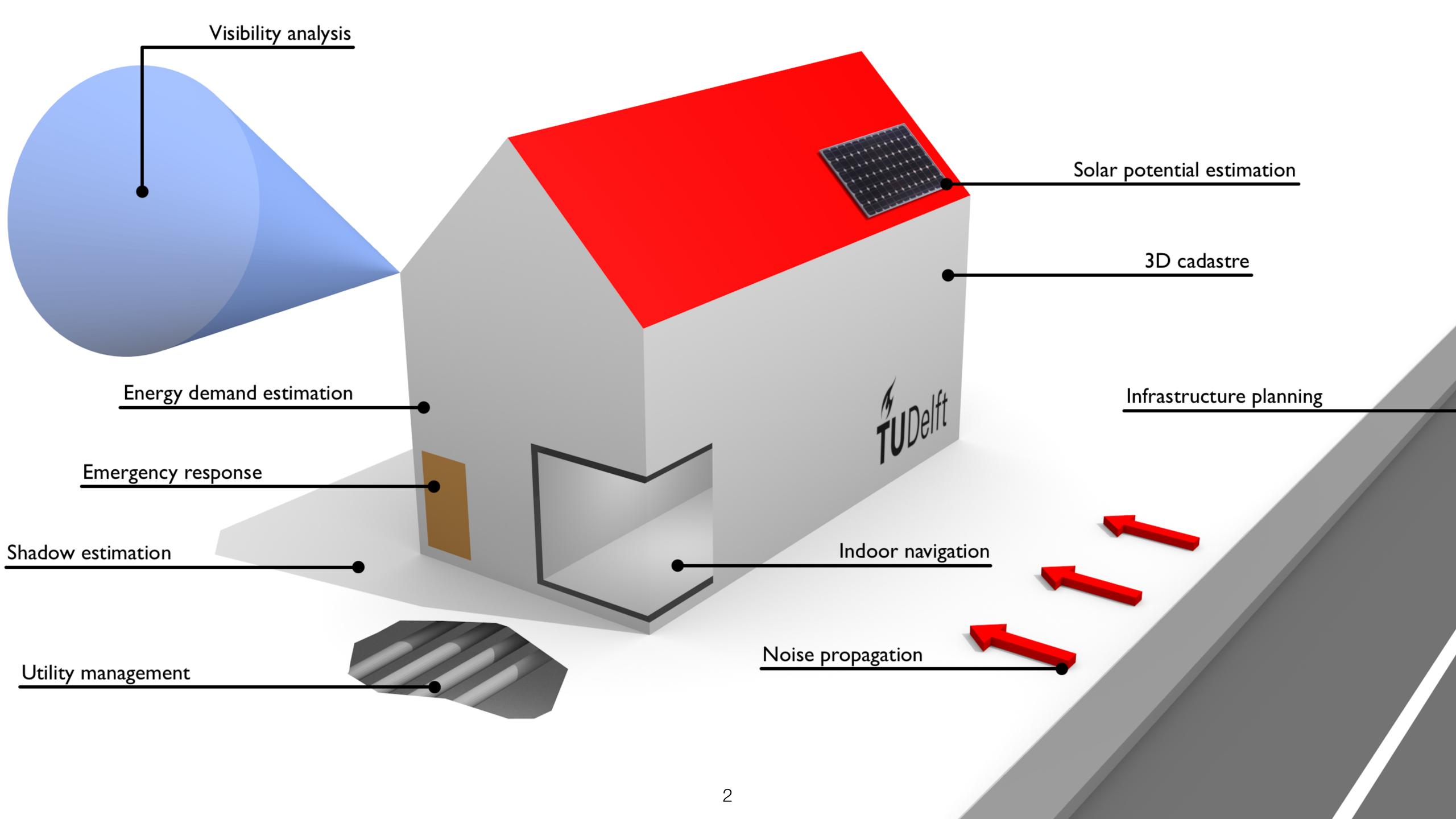
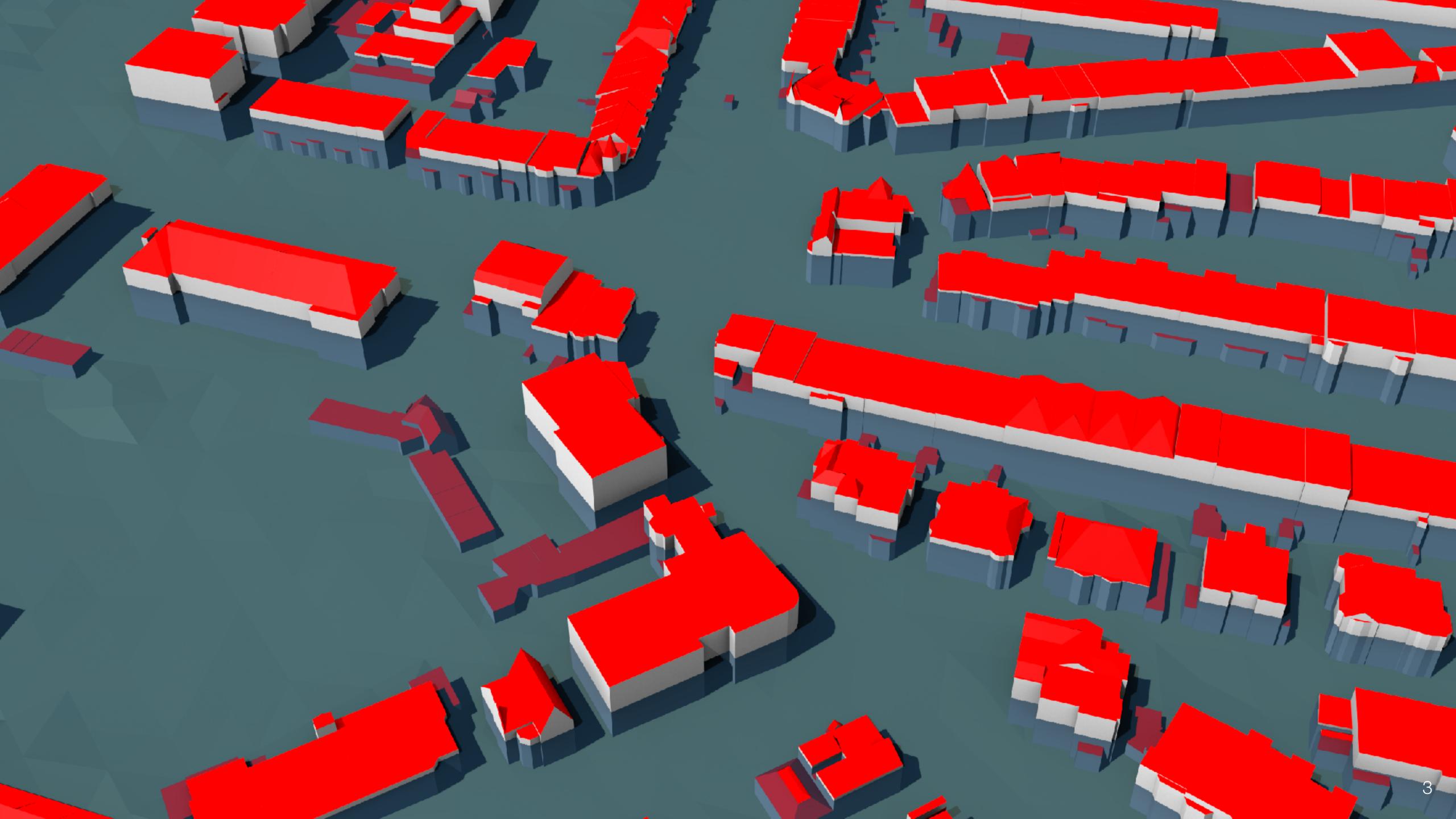
#### Applications of 3D modelling of the built environment

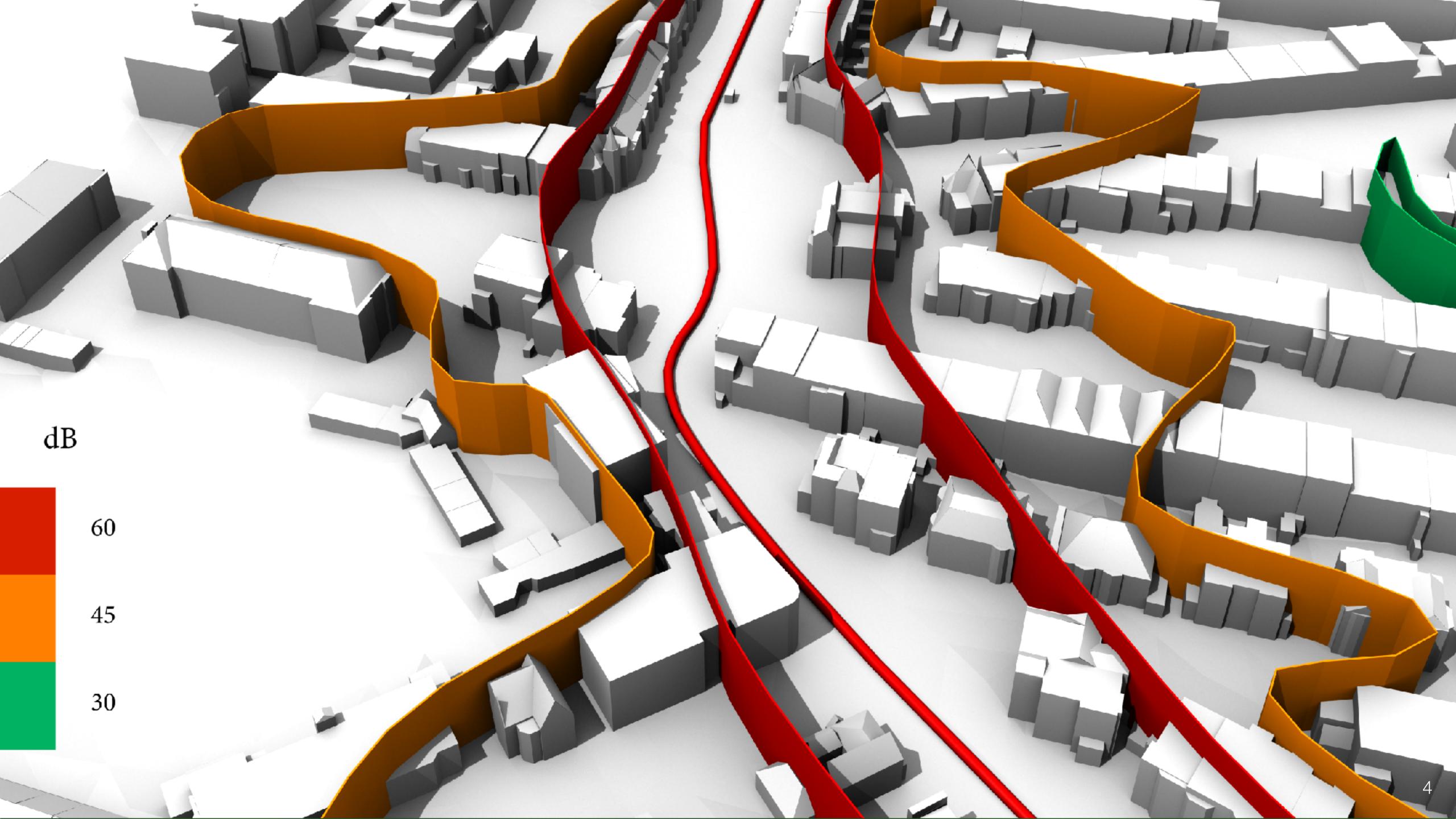
GEO1004:

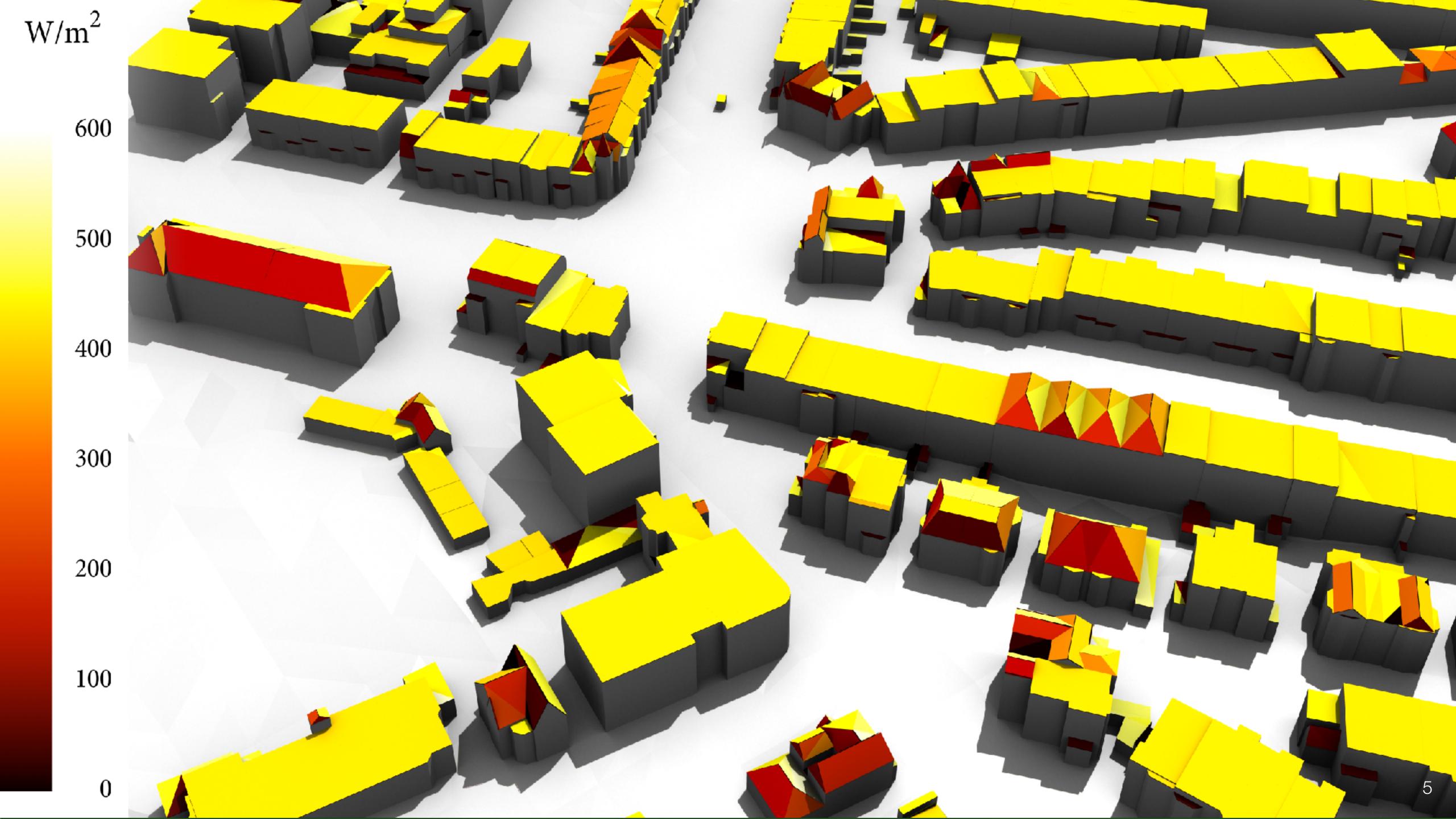
3D modelling of the built environment

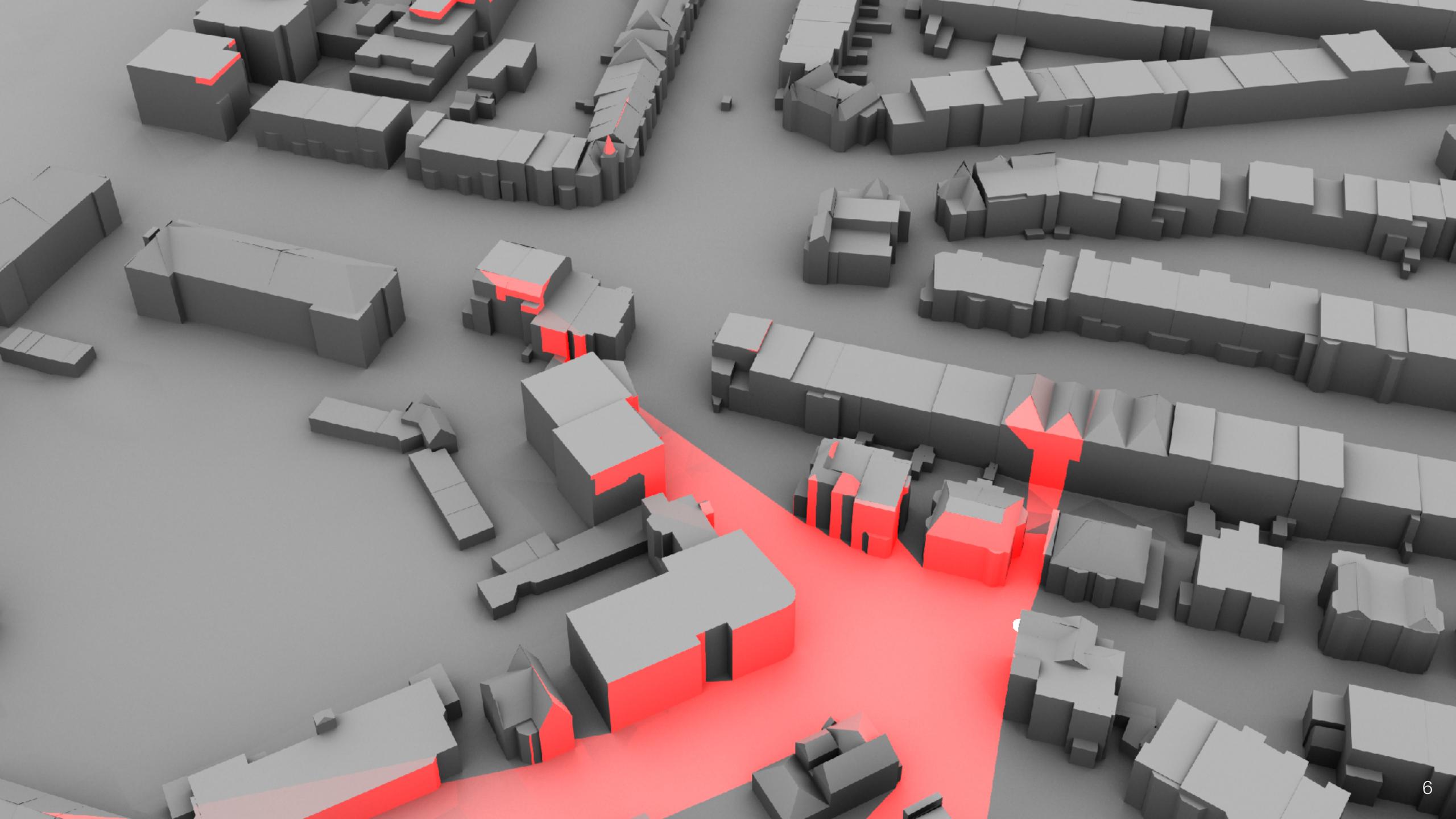












#### Other applications

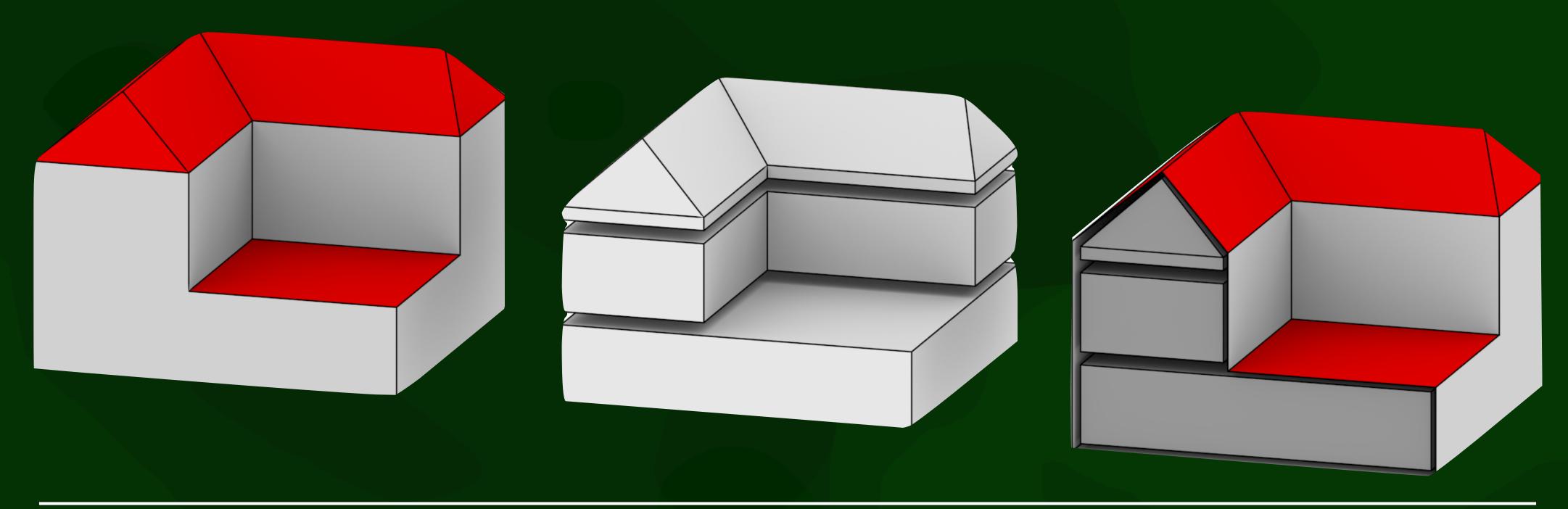
- Energy demand estimation (and potential for retrofitting)
- Visualisation (eg for gaming, tourism, navigation, etc)
- Computational fluid dynamics (eg for wind speeds, air quality, effects on buildings, etc)
- Shadow casting (eg for building permits, visibility analysis, improving energy demand/solar potential calculations, etc)

#### 4 MSc Geomatics theses

- Motivation: create (rough) indoor geometry from widely available outdoor geometry
- Definition of a CityGML LOD2 with interiors (LOD2+)
- Compute interior geometry from exterior geometry + number of storeys
- Compute net internal area

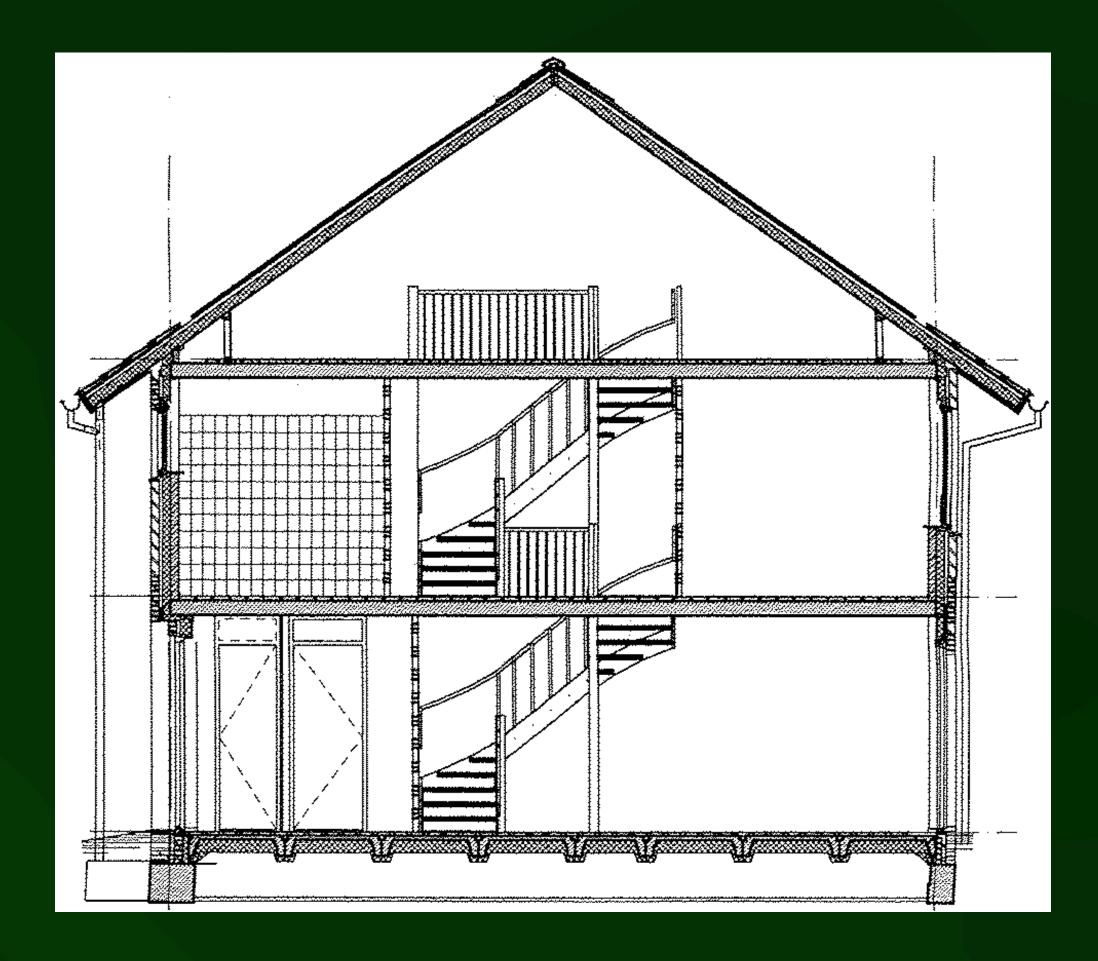


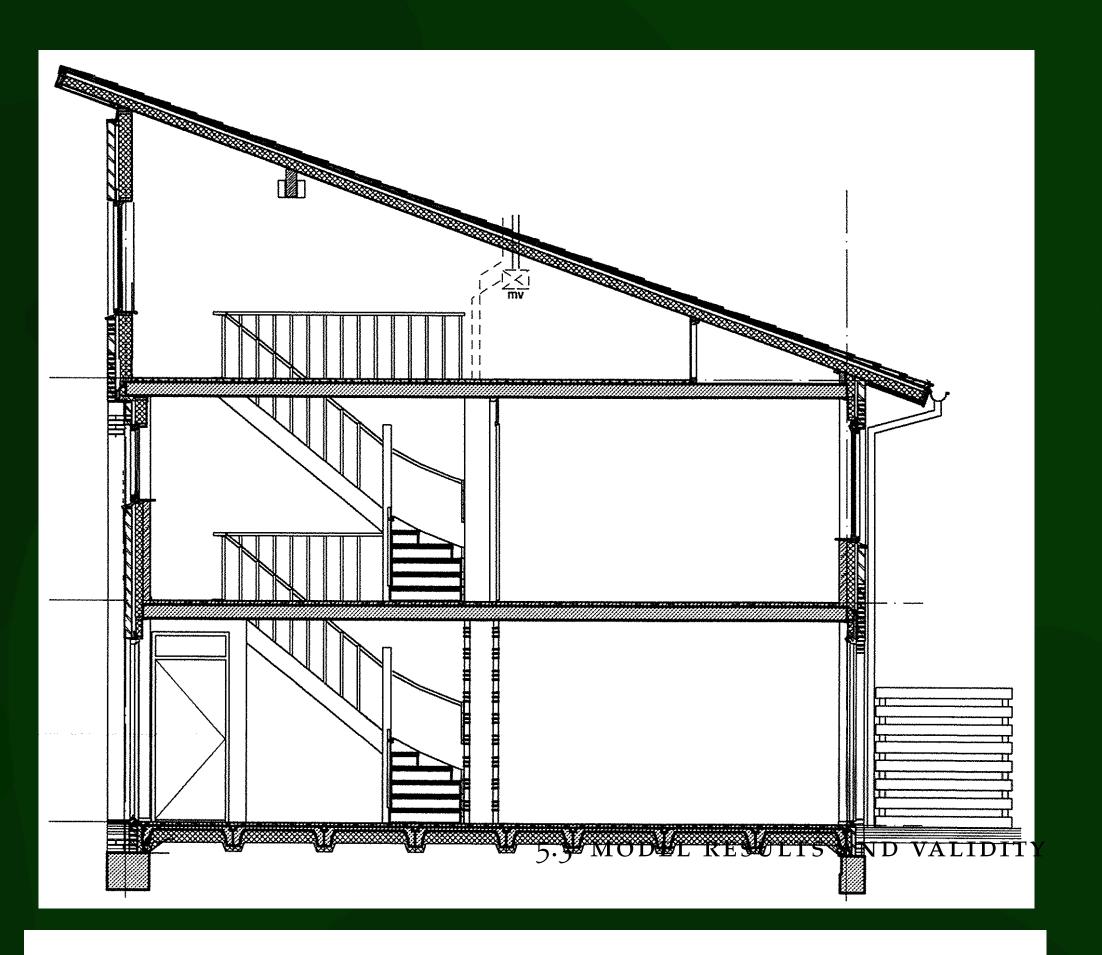
## LOD2+



Exterior in LOD2	Interior in LOD2+
Buildings bodies are prisms Simple roof shapes Thematically classified boundary surfaces No openings in the exterior geometry	Storeys within building bodies are prisms Attic storey shapes corresponding to roof shapes Thematically classified boundary surfaces No openings in the indoor geometry

## Indication of storeys

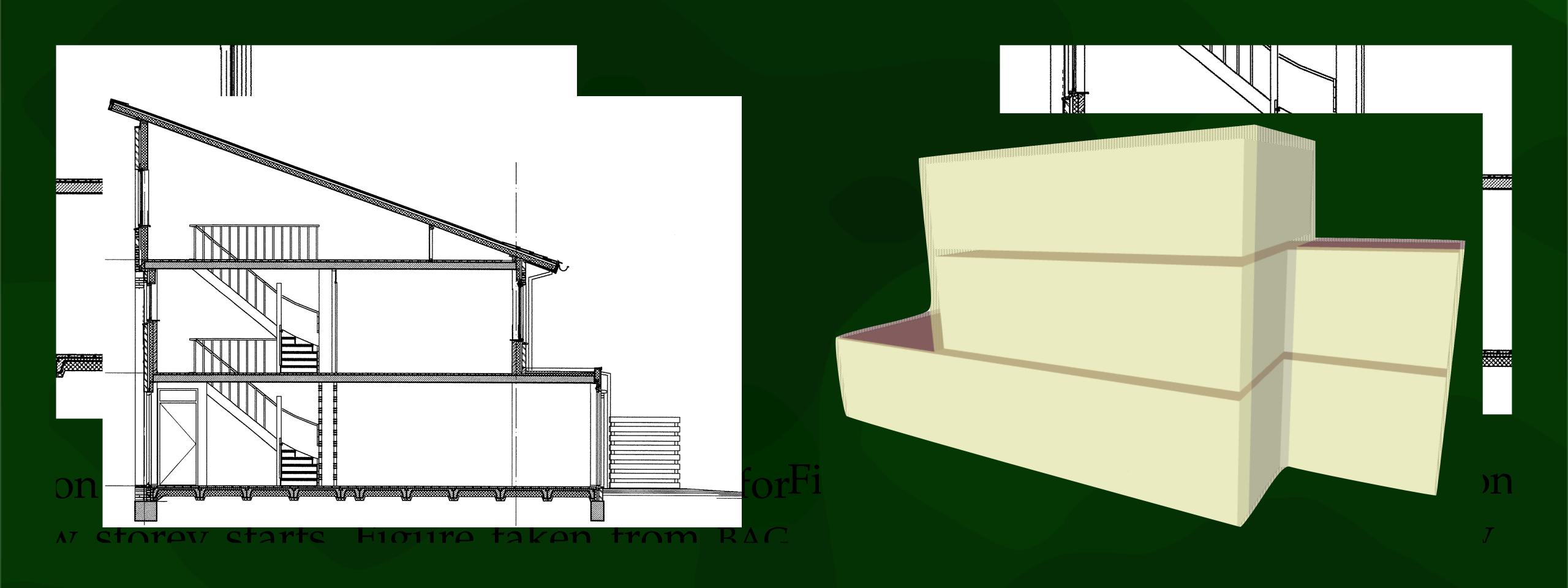




5.2 GENERATION RULES AND DATA IN

77

## Indication of storeys



#### Wall thickness

Type	year y	storeys x	$t_{\rm ext}$ [cm]	$t_{ m shared}$ [cm]
Non-stacked	y < 1970	$x \leq 2$	27	11
		$x \ge 3$	27	12
	$1970 \le y \le 1985$	x = 2	27	10
		x = 3	28	12
		x = 4	27	9
	y > 1985	x = 2	28	13
		x = 3	<b>30</b>	12
		x = 4	25	12
Stacked	<i>y</i> < 1970	$x \leq 5$	29	12
		$5 < x \le 10$	38	11
		x > 10	25	9
	$1970 \le y \le 1985$	$x \leq 5$	28	11
		$5 < x \le 10$	26	11
		x > 10	29	12
	y > 1985	$x \leq 5$	30	12
		$5 < x \le 10$	38	13
		x > 10	35	15
Other types	y < 1970	x = 1	14	14
		$x \ge 2$	31	11
	$1970 \le y \le 1985$	x = 1	14	14
		$x \ge 2$	<b>30</b>	10
	y > 1985	x = 1	14	14
		$x \ge 2$	36	13

This robot can have different shapes. If an exact buffer is required in all direction that the section is required in all directions of the section in the section in the section is required in the section in the section in the section is required in the section in the section in the section is required in the section in the section in the section is required in the section in the section in the section is required in the section in the section in the section in the section is required in the section in the sect sive operation and runs in  $O(n^3m^3)$  where n and m are the sum of vertices, halfedges and shalfedges of polyhedron 1 and polyhedron 2 respectively (Hachenberger, 2007). A quick performance test shows that Minkowski sum of a triangular face with an approximated sphere (wi<mark>th 80 triangu</mark>lar facets and 42 vertices) takes about 2-3 times longer than Minkowski sum with a cube whereas the accuracy in the perpendicular offset is then still limited. Therefore a cube is chosen as robot, which is expected to be good enough as the walls of most buildings are perpendicular to each other.

The Minkowski-sum-is-the-vector sum-of-the-point-sets of both polyhedra. Therefore when using a cube for applying the offset, a rotation should be applied. This is illustrated for a 2-dimensional case in Figure 39. The offset to the line is not the same for both cases. A rotation thus needs to be applied, such that the square is aligned with

5° 0°---

14

ouffered face from the original solid (set difperation)

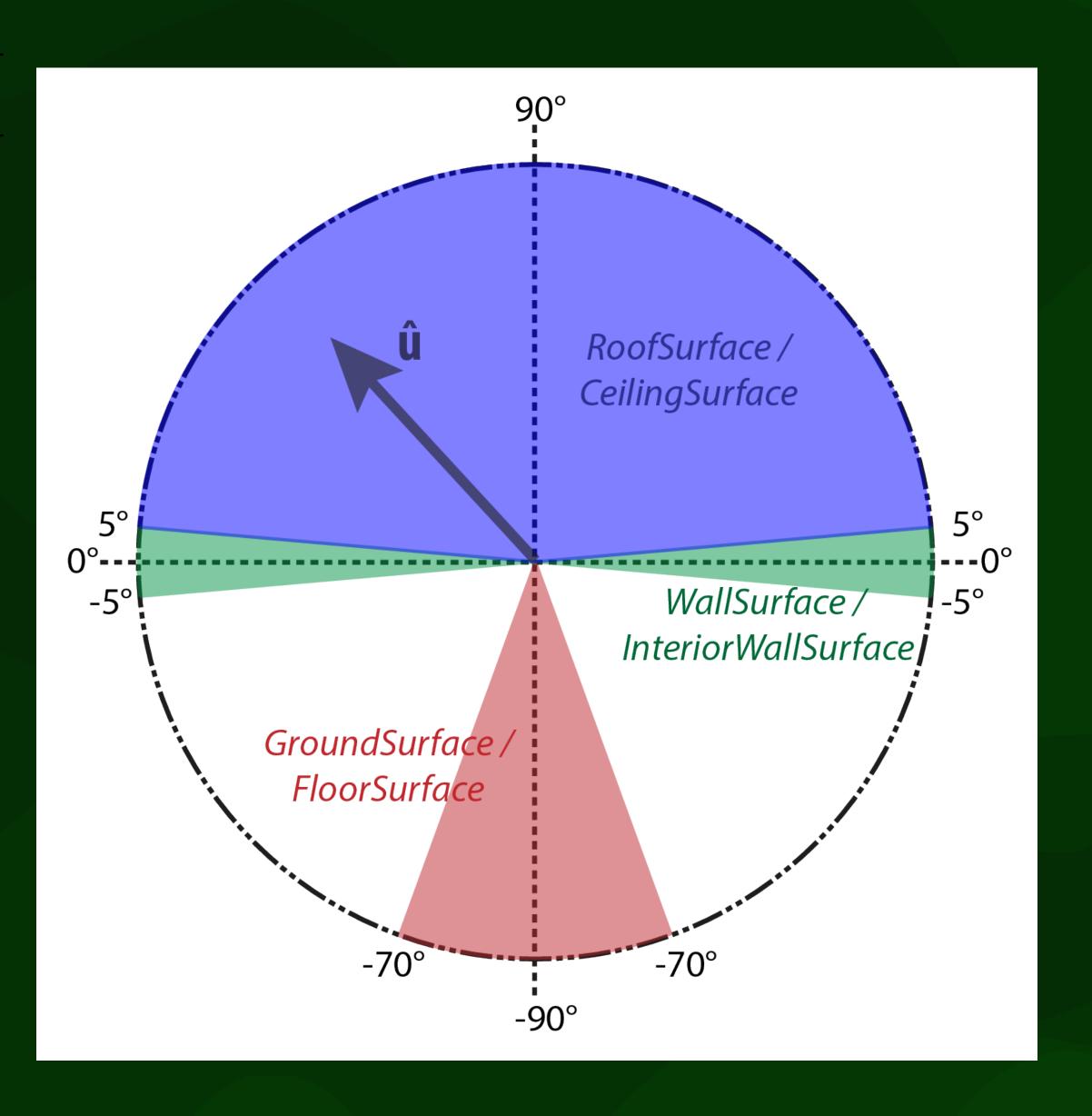
erent shapes. If an exact buffer is required in should be a sphere where the radius equals ortunately the Minkowski sum is an expension of the Minkowski sum is an expension of the sum of the sum of the sum of a triangular face with an approximated ar facets and 42 vertices) takes about 2-3 times sum with a cube whereas the accuracy in the then still limited. Therefore a cube is chosen cted to be good enough as the walls of most cular to each other.

is the vector sum of the point sets of both when using a cube for applying the offset, a sed. This is illustrated for a 2-dimensional case to the line is not the same for both cases. A seapplied, such that the square is aligned with the robot must be scaled such that the radius sheed to be handled separately so that in the out-

of which the normal vectory of which the normal vectory and an anger than 100°, thereby exclude heights are extracted by containing height. Whether this height is marked as characteristic.

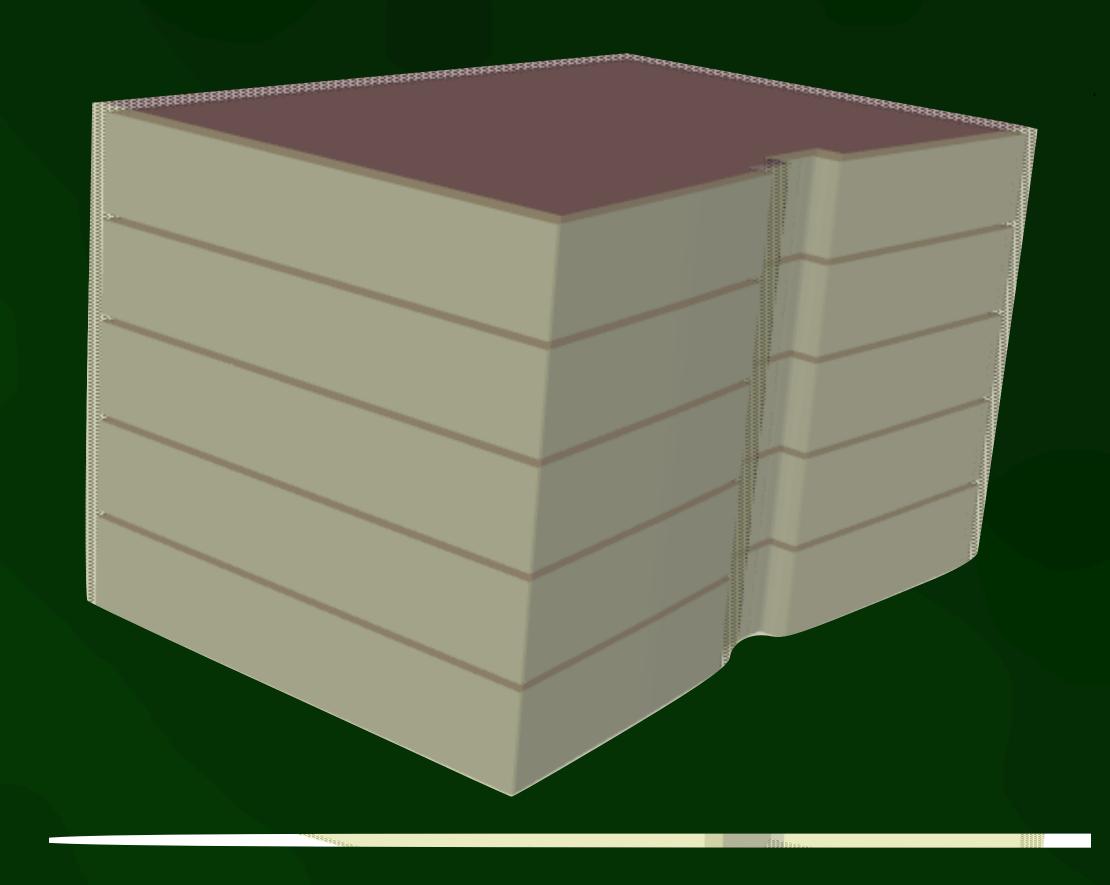
mption is that each storey has the same height, sates with the street of the line. total height can be divided by the amount of heights at which the built a must be split.

## Classifying surfaces

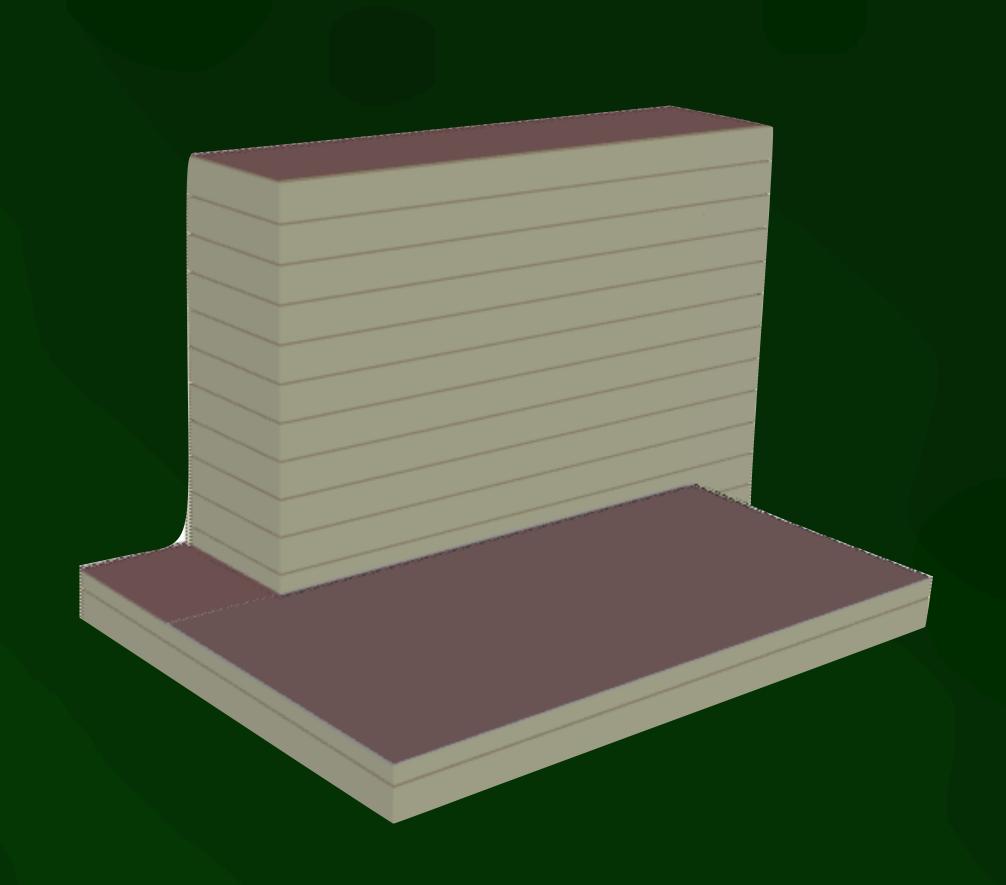




are not snapped to the eaves of the root, because the distance between

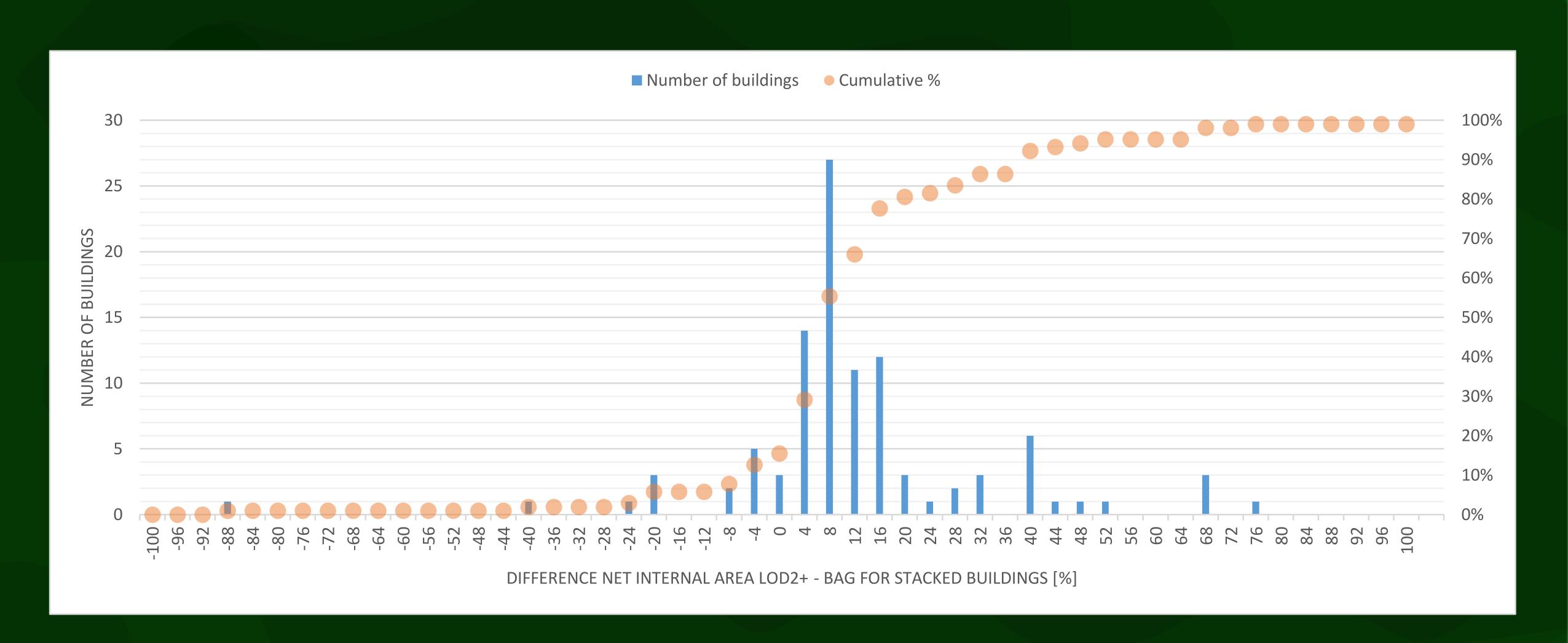




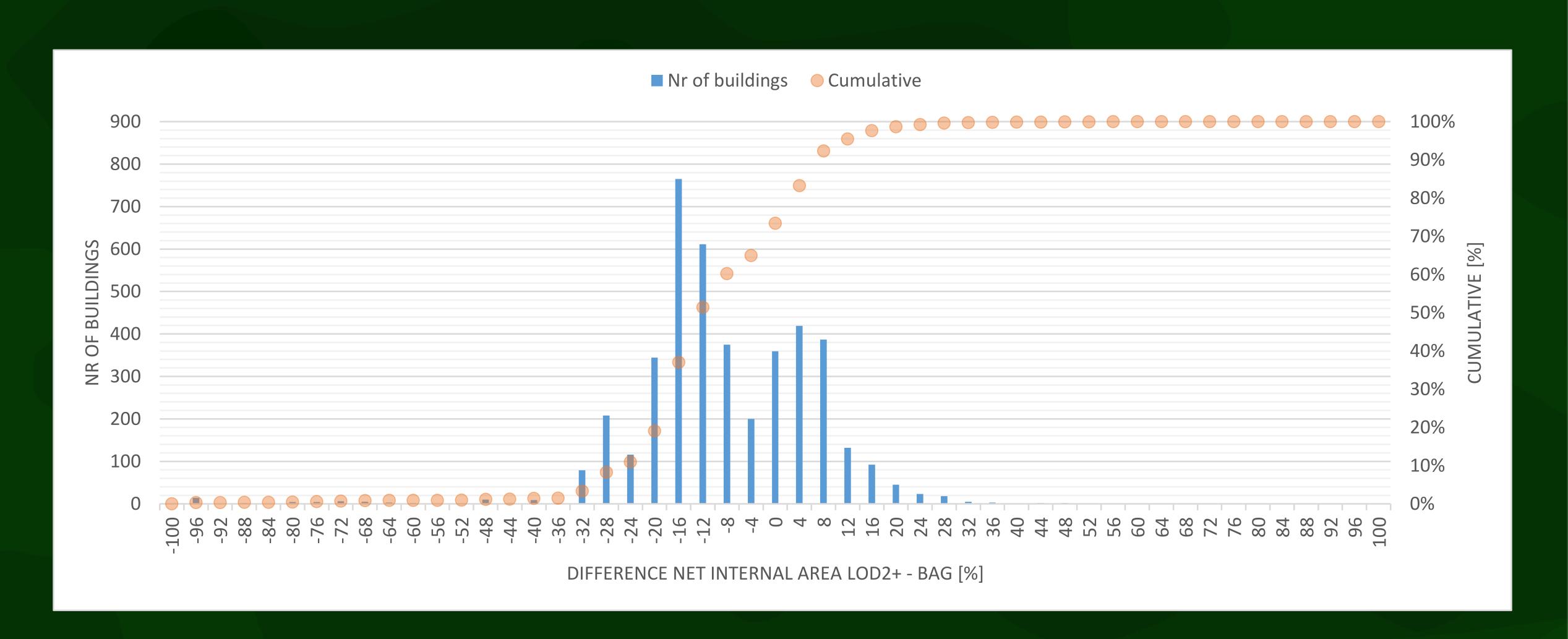




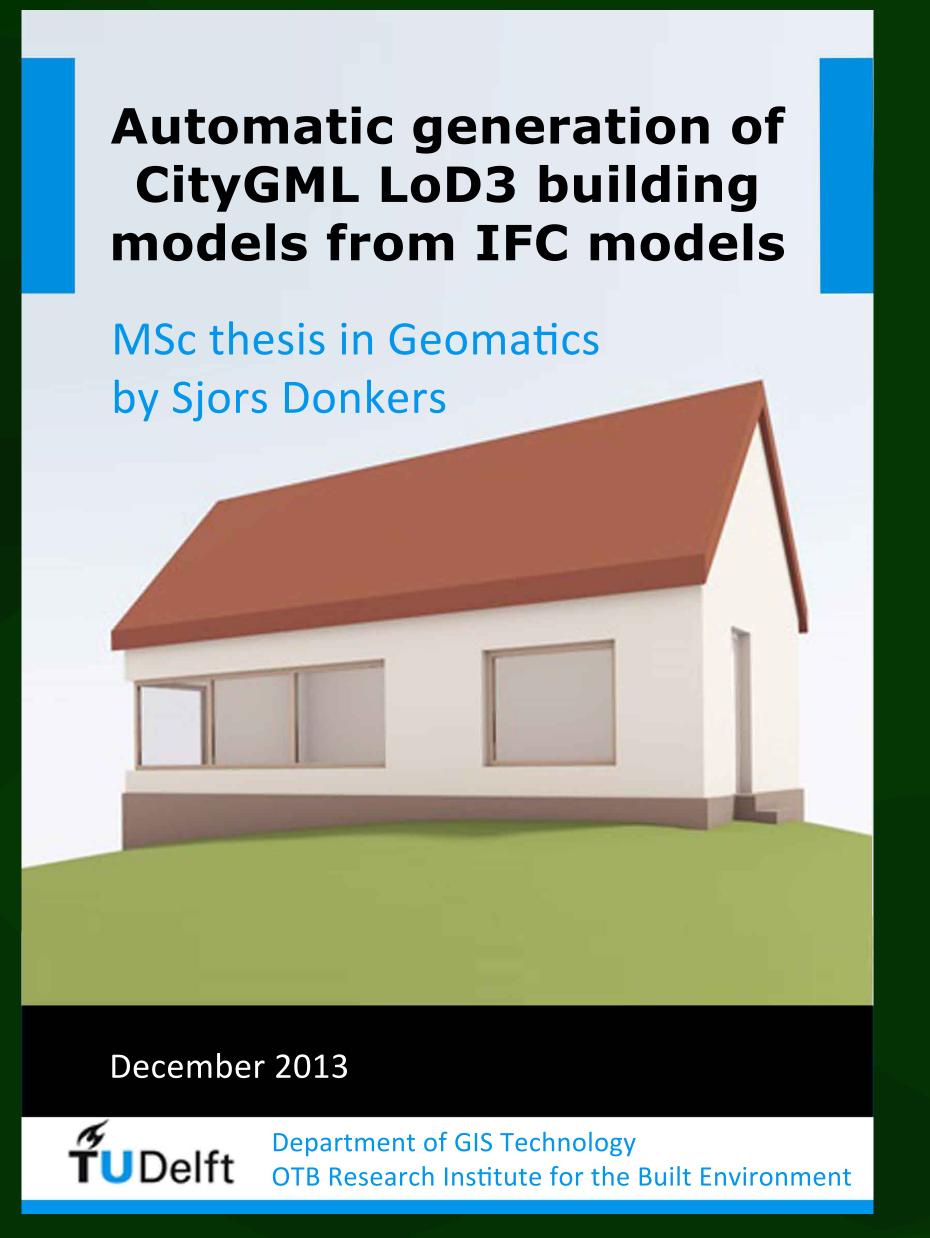
#### Net internal area (stacked)



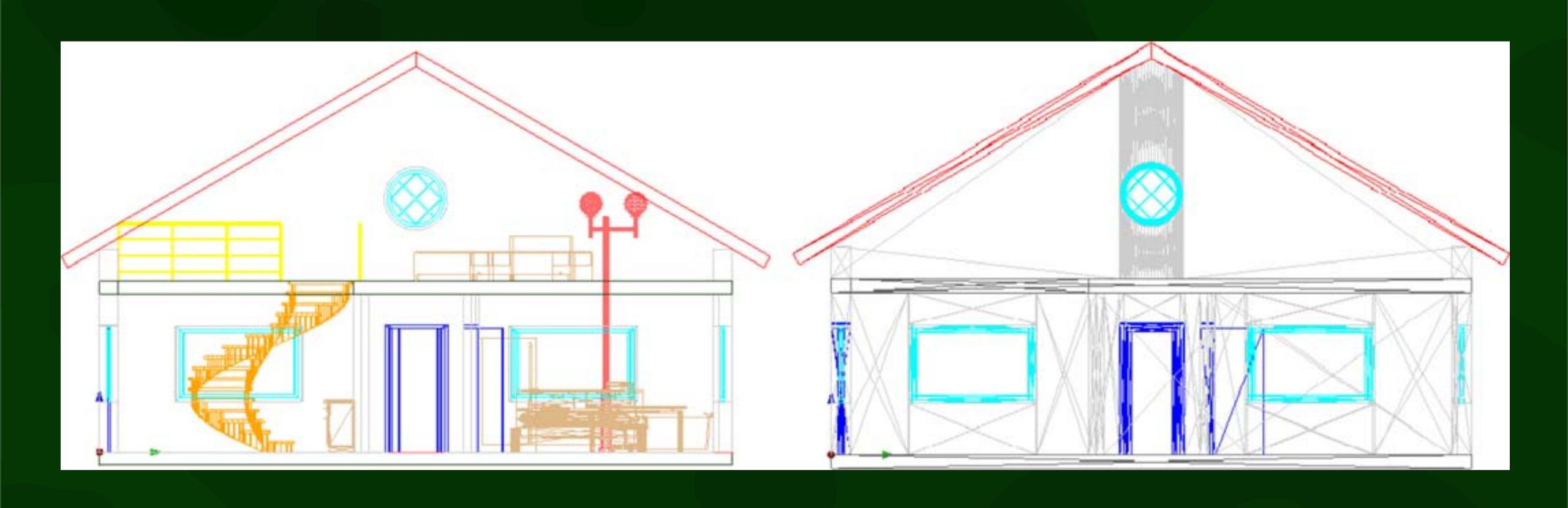
#### Net internal area (non-stacked)



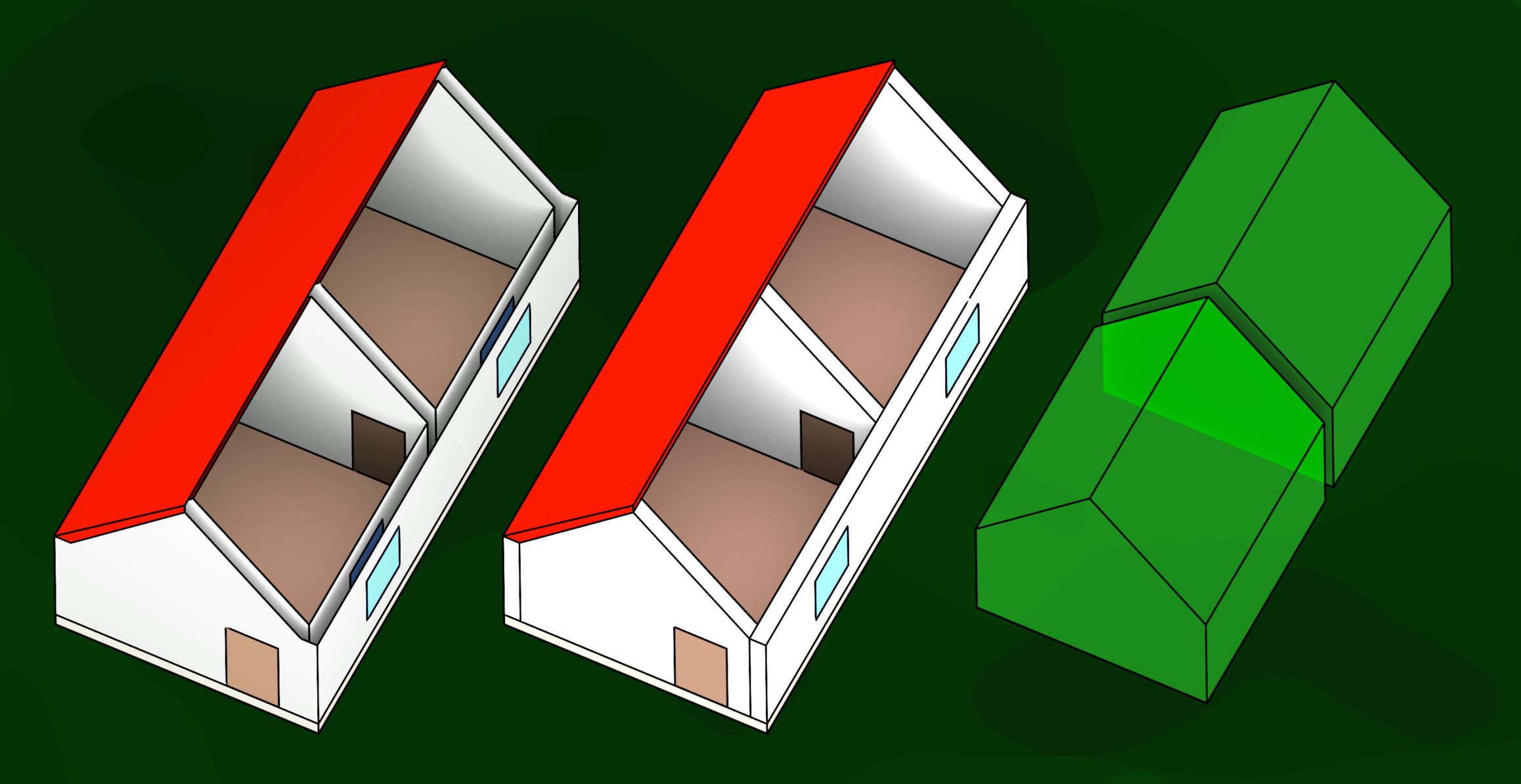
- Motivation: update 3D city models from designed BIM models (including potentially interiors)
- Fill gaps using Minkowski sum to increase size of elements
- Merge elements using Boolean set union
- Reclassify surfaces



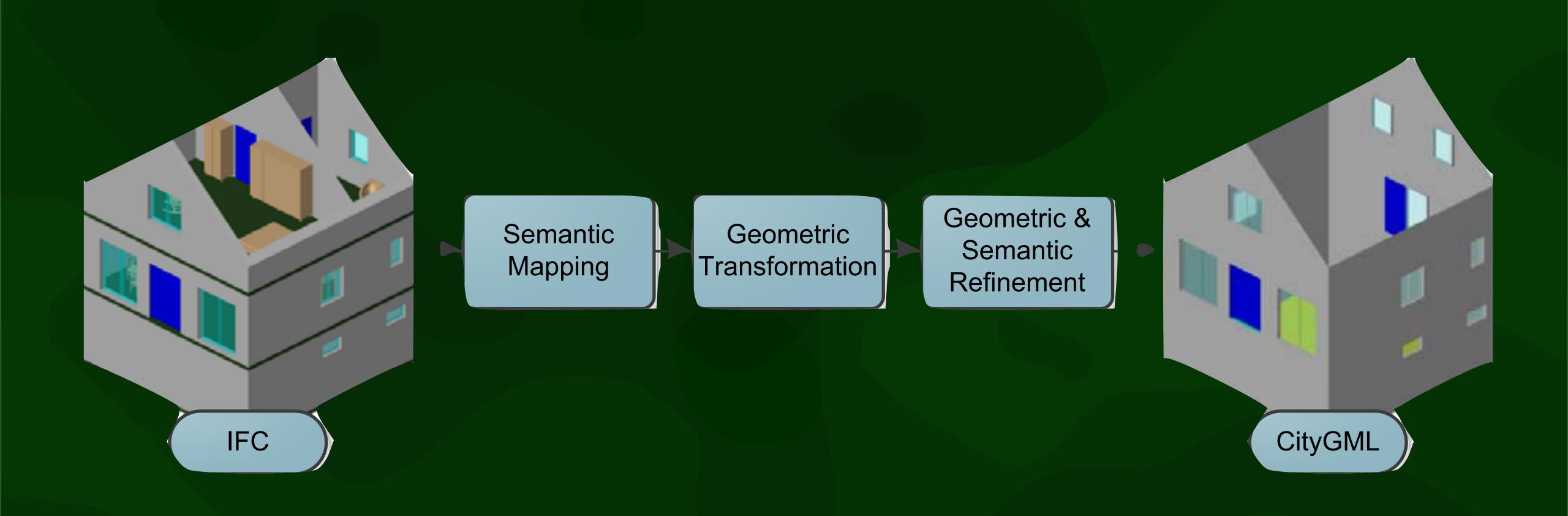
## Goal



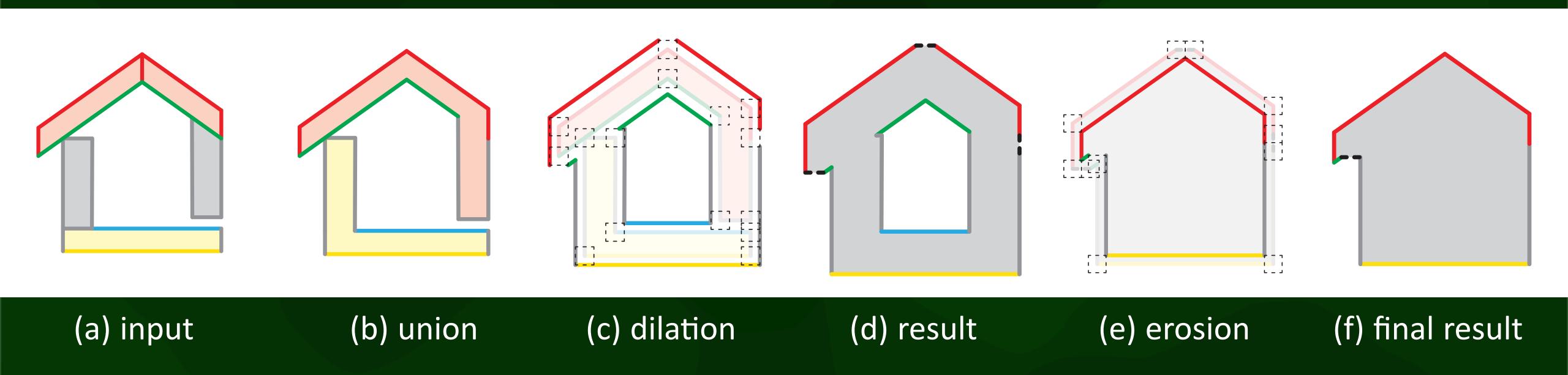
## 3DCM vs BIM

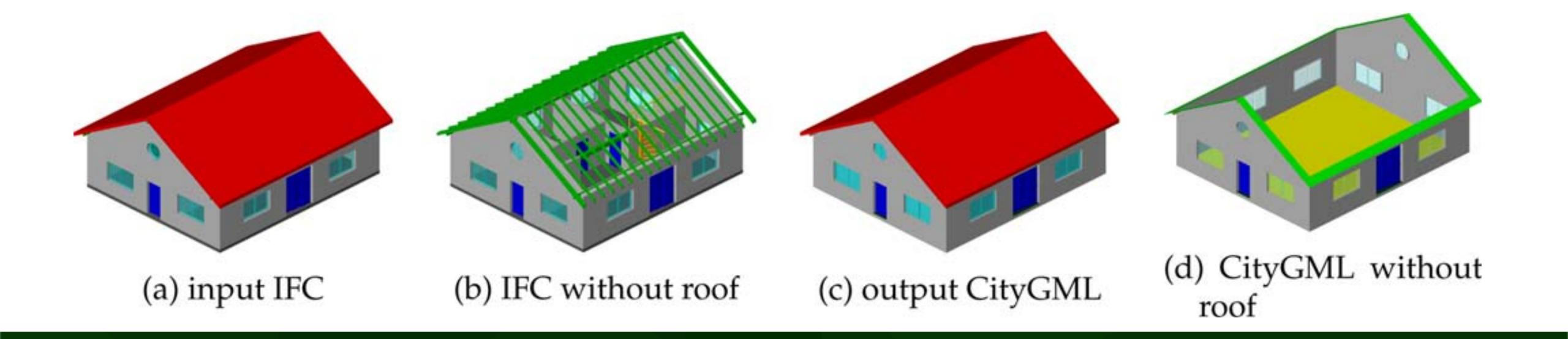


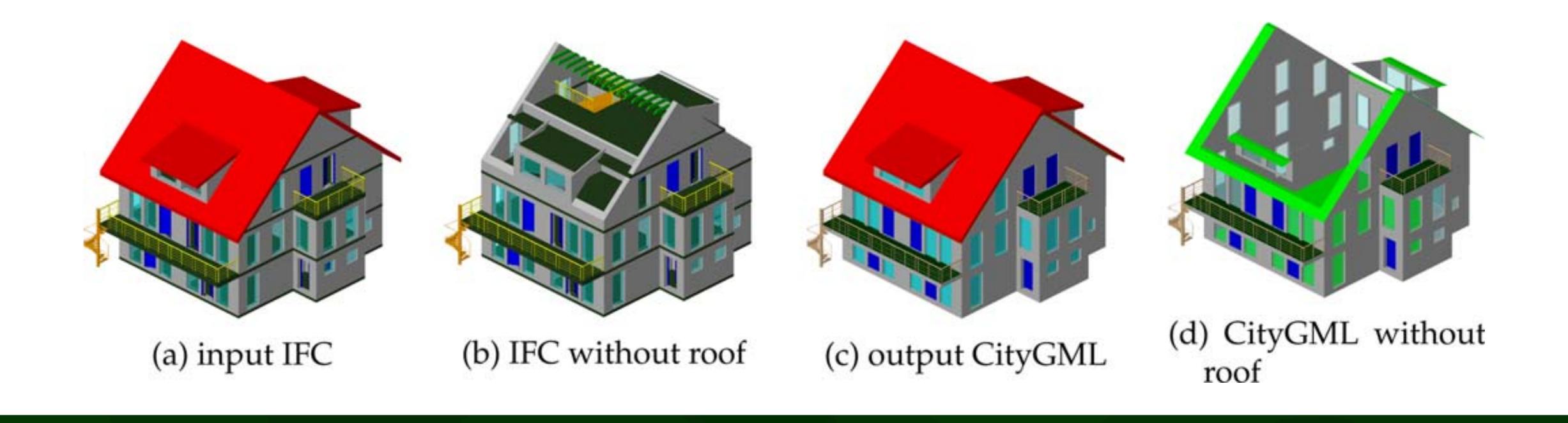
## Methodology (semantics)

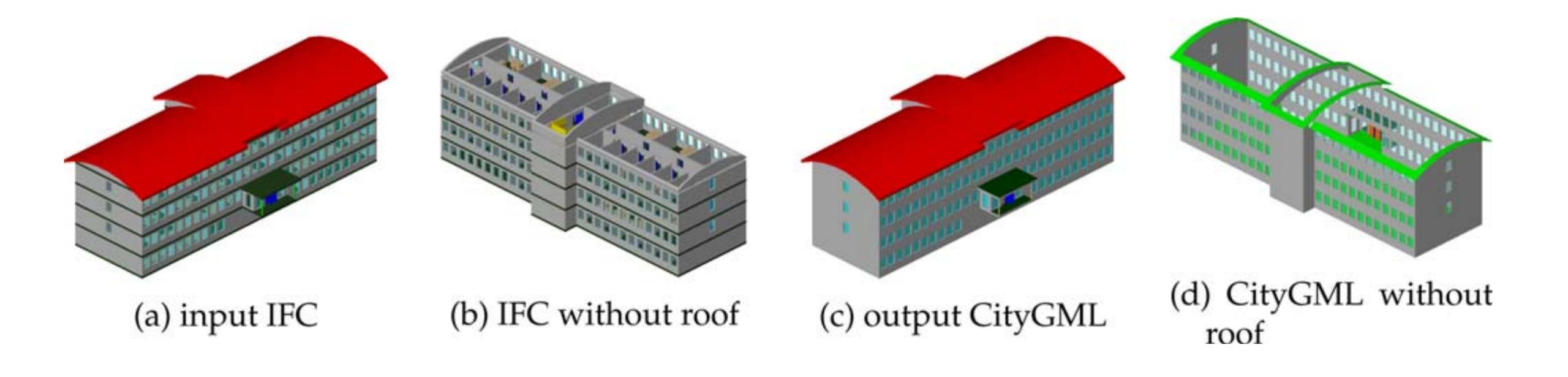


# Methodology (geometry)

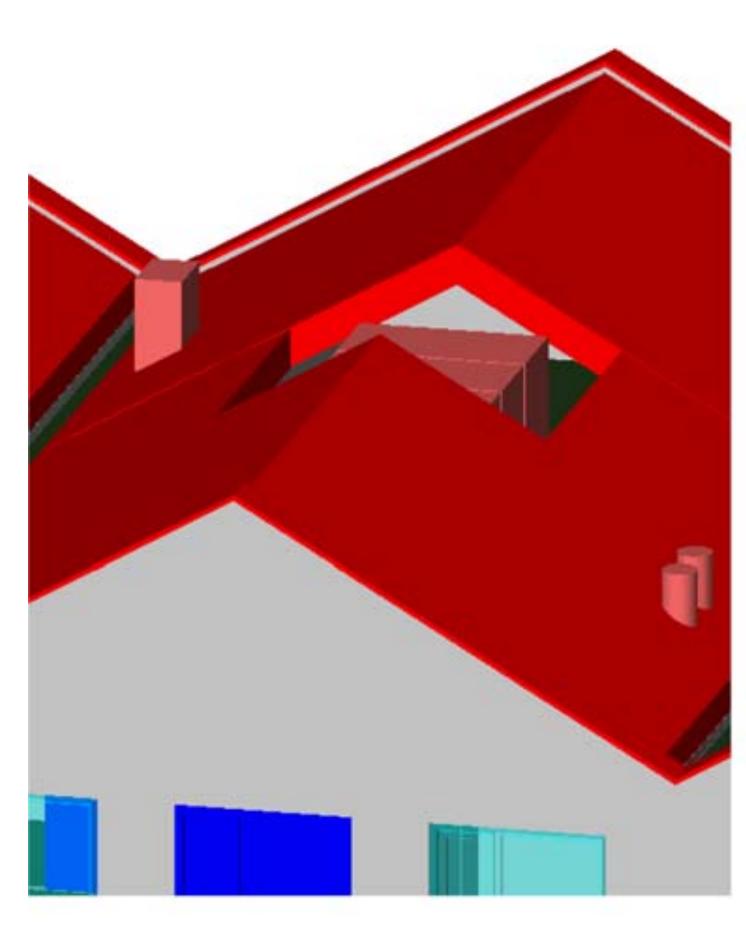




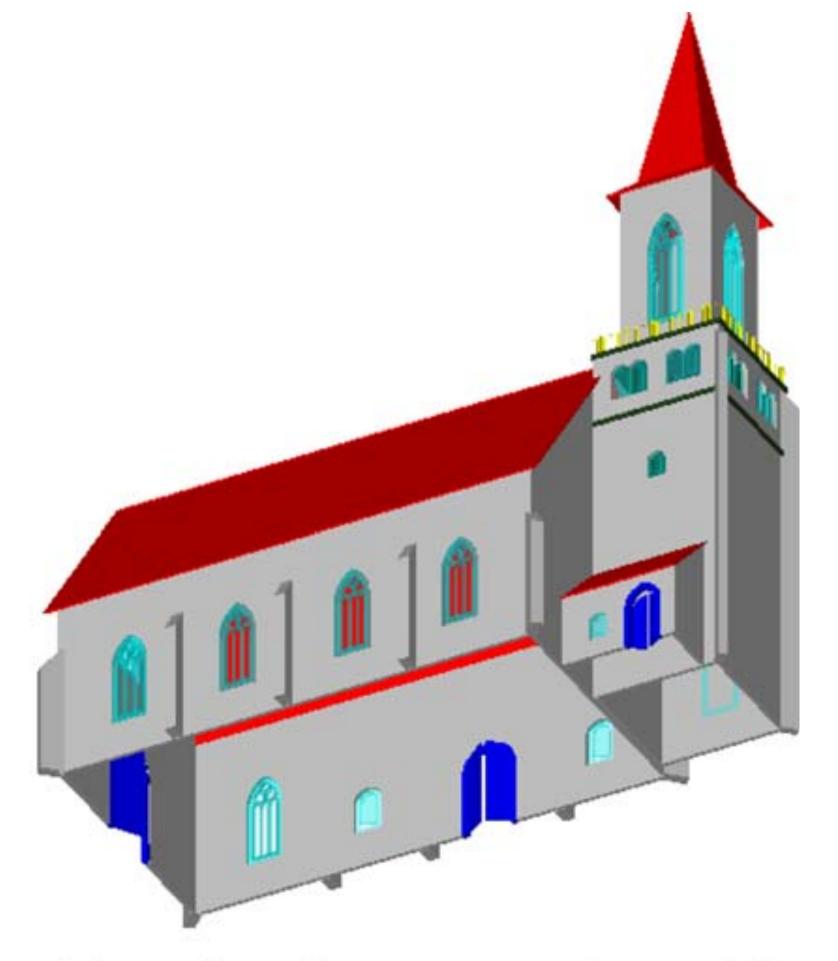




#### Issues



(a) Building where part of the roof is missing

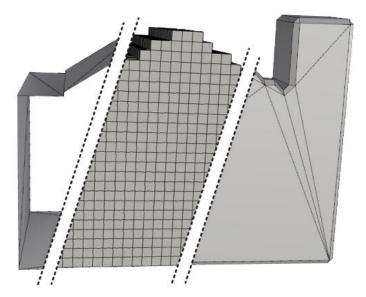


(b) A church missing a base slab

#### Motivation: repair 3D models so that they can be used in applications

- Voxelisation
- Reconstruction of mesh
- Obtain semantics and export

#### AUTOMATIC REPAIR OF 3D CITY BUILDING MODELS USING A VOXEL-BASED REPAIR METHOD



A thesis submitted to the Delft University of Technology in partial fulfillment of the requirements for the degree of

Master of Science in Geomatics

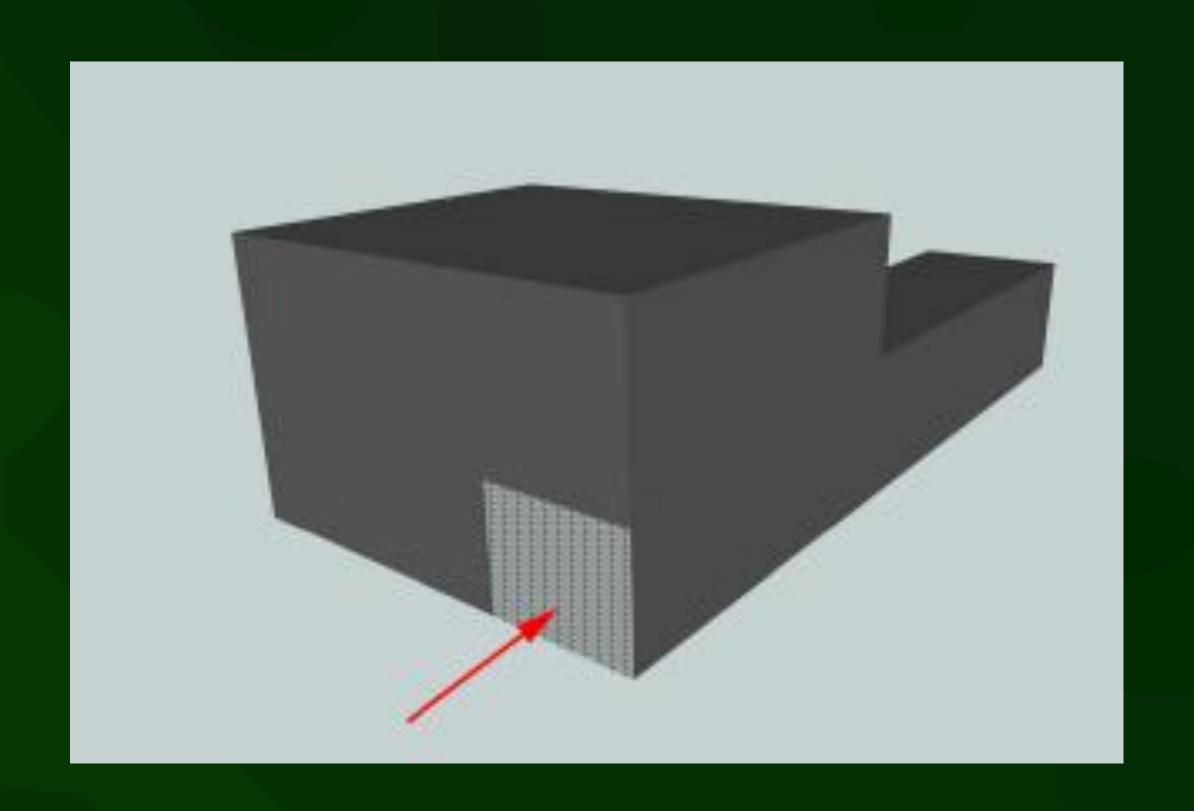
bv

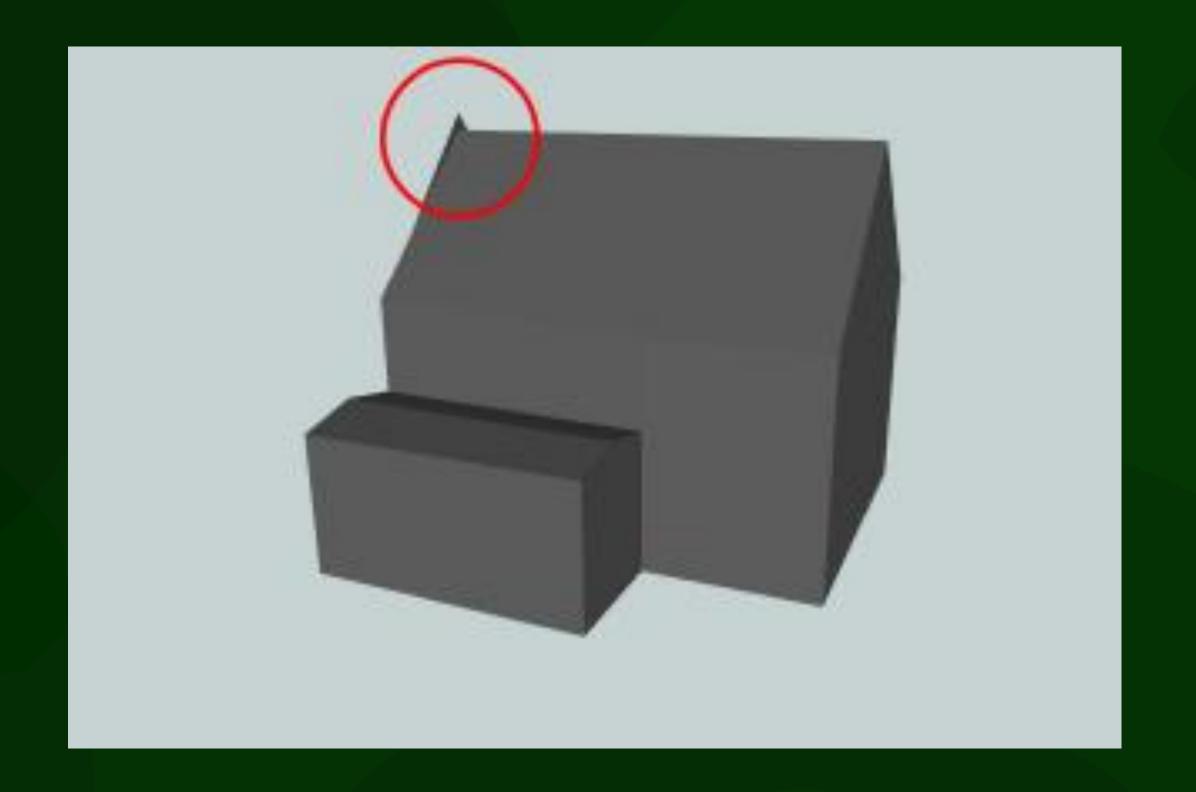
Damien Mulder

M.Sc Geomatics Thesis

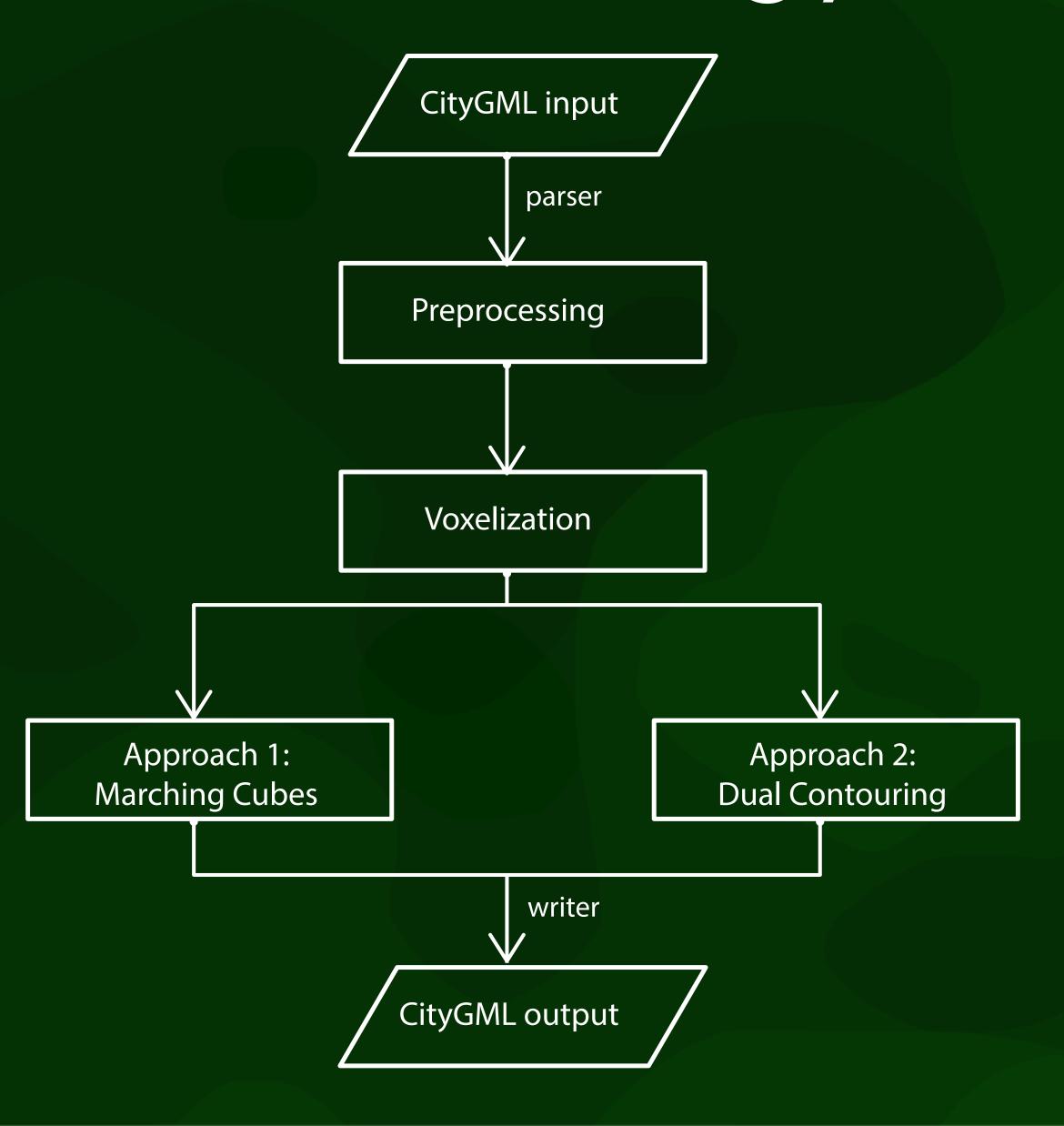
June 2015

# Fixing 3D models

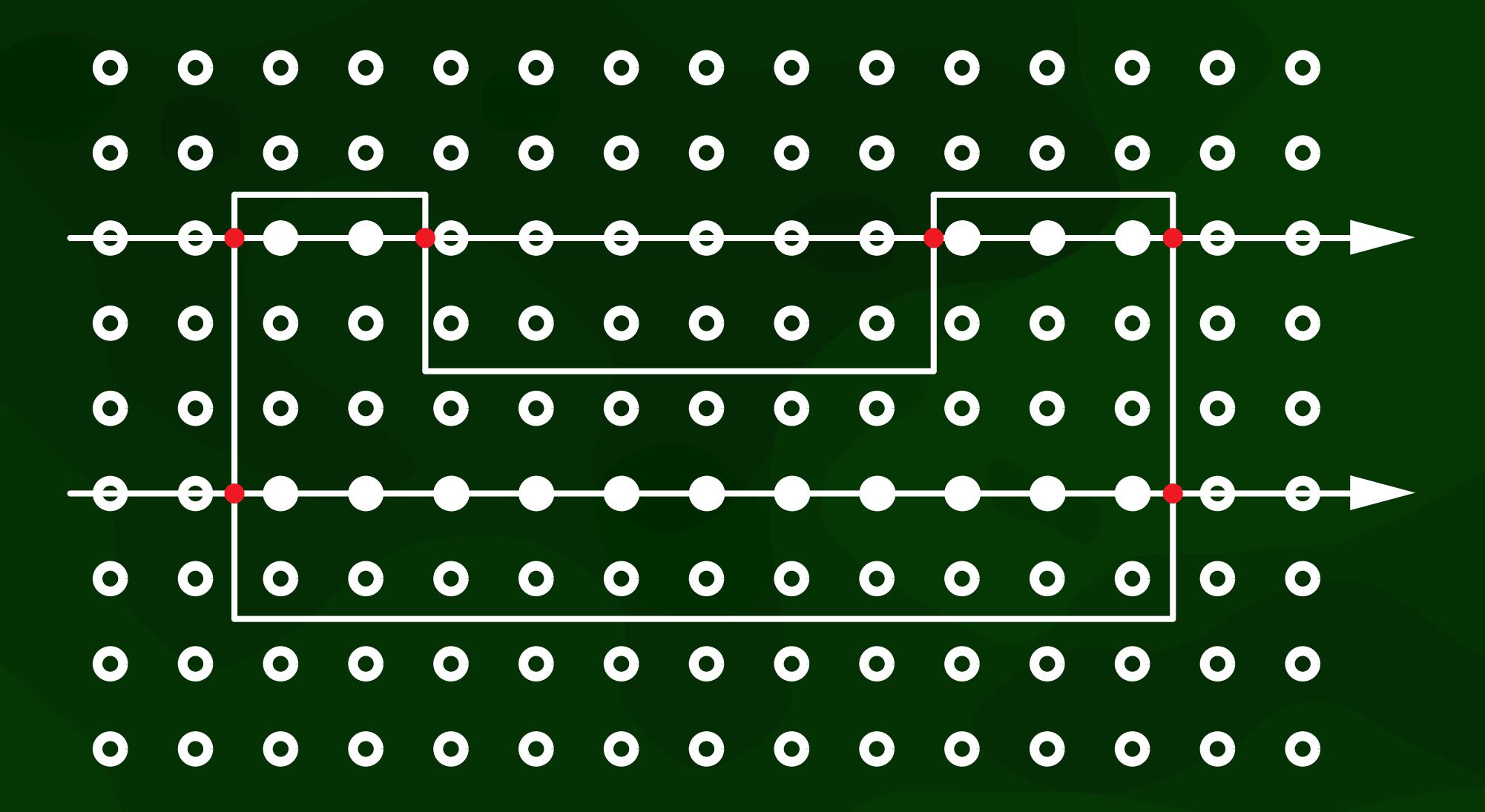




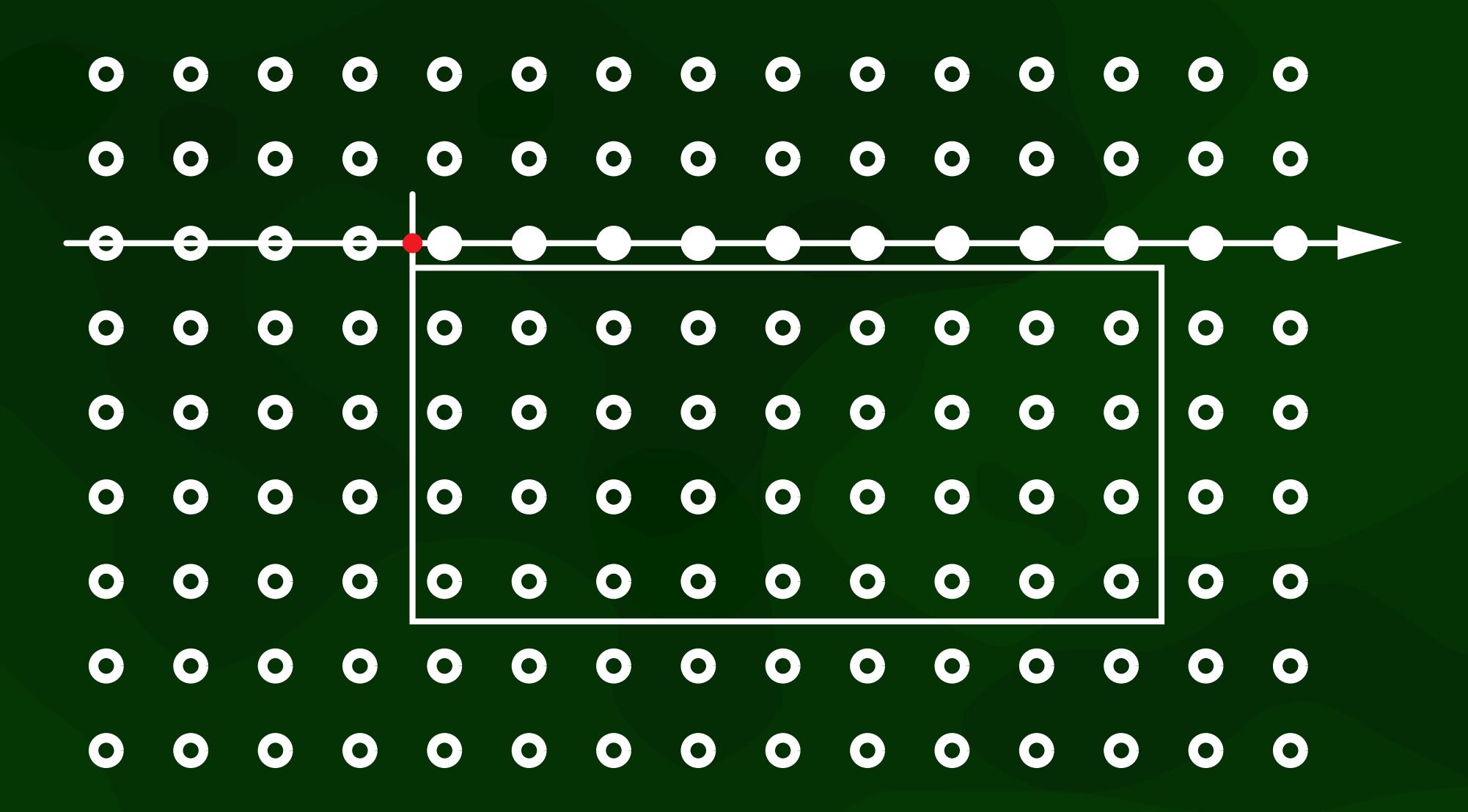
# Methodology



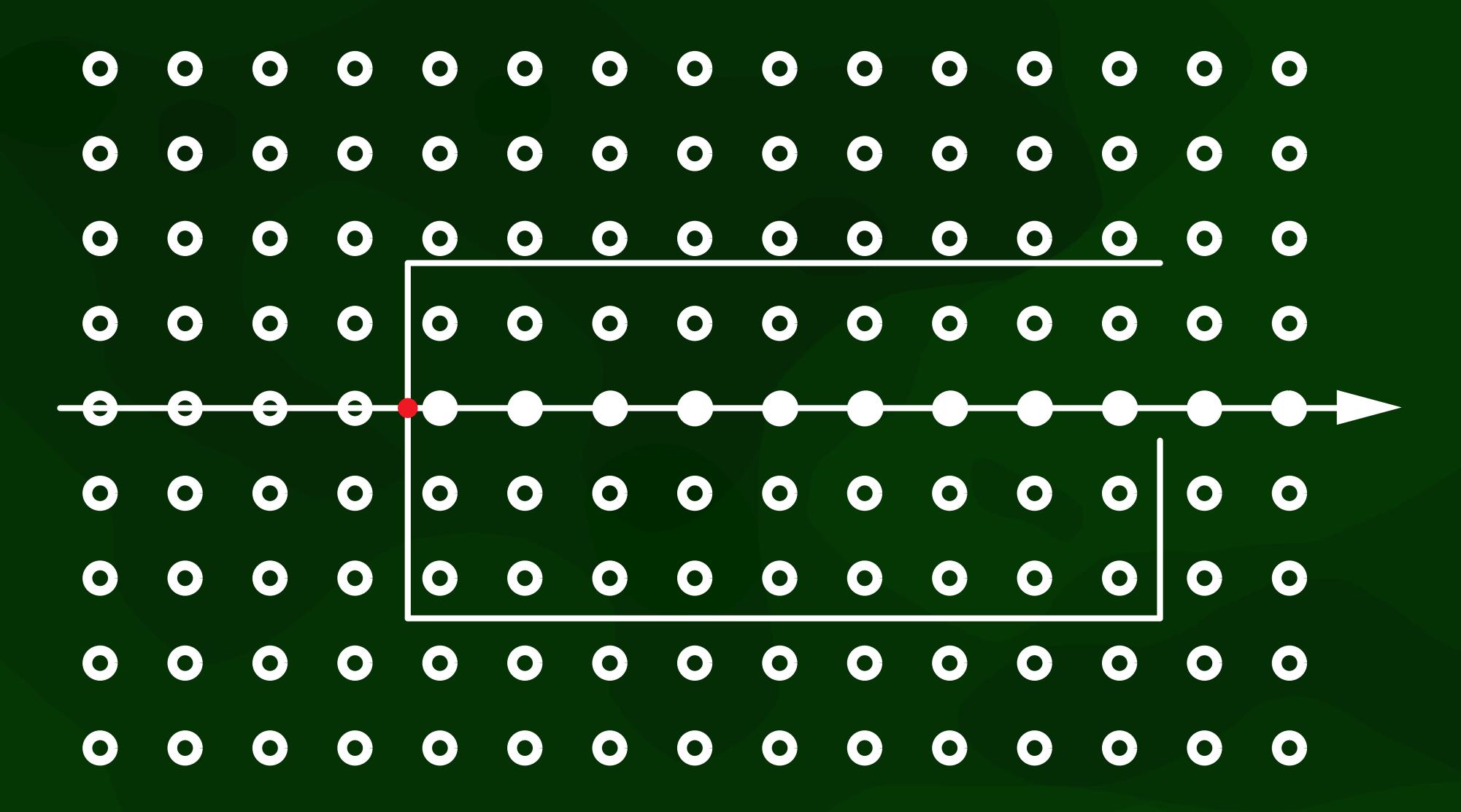
#### Voxelisation



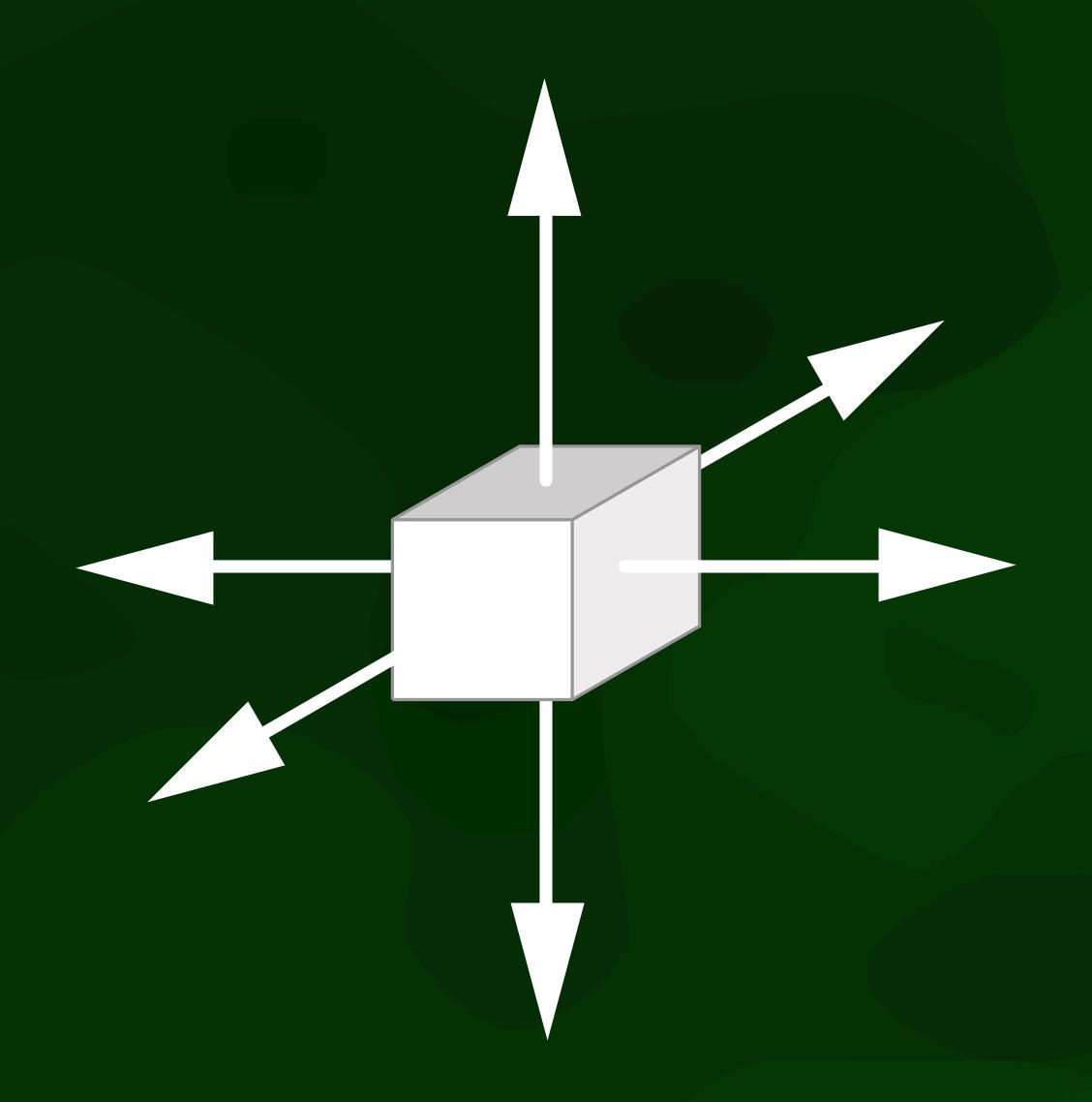
#### Voxelisation: overshoot



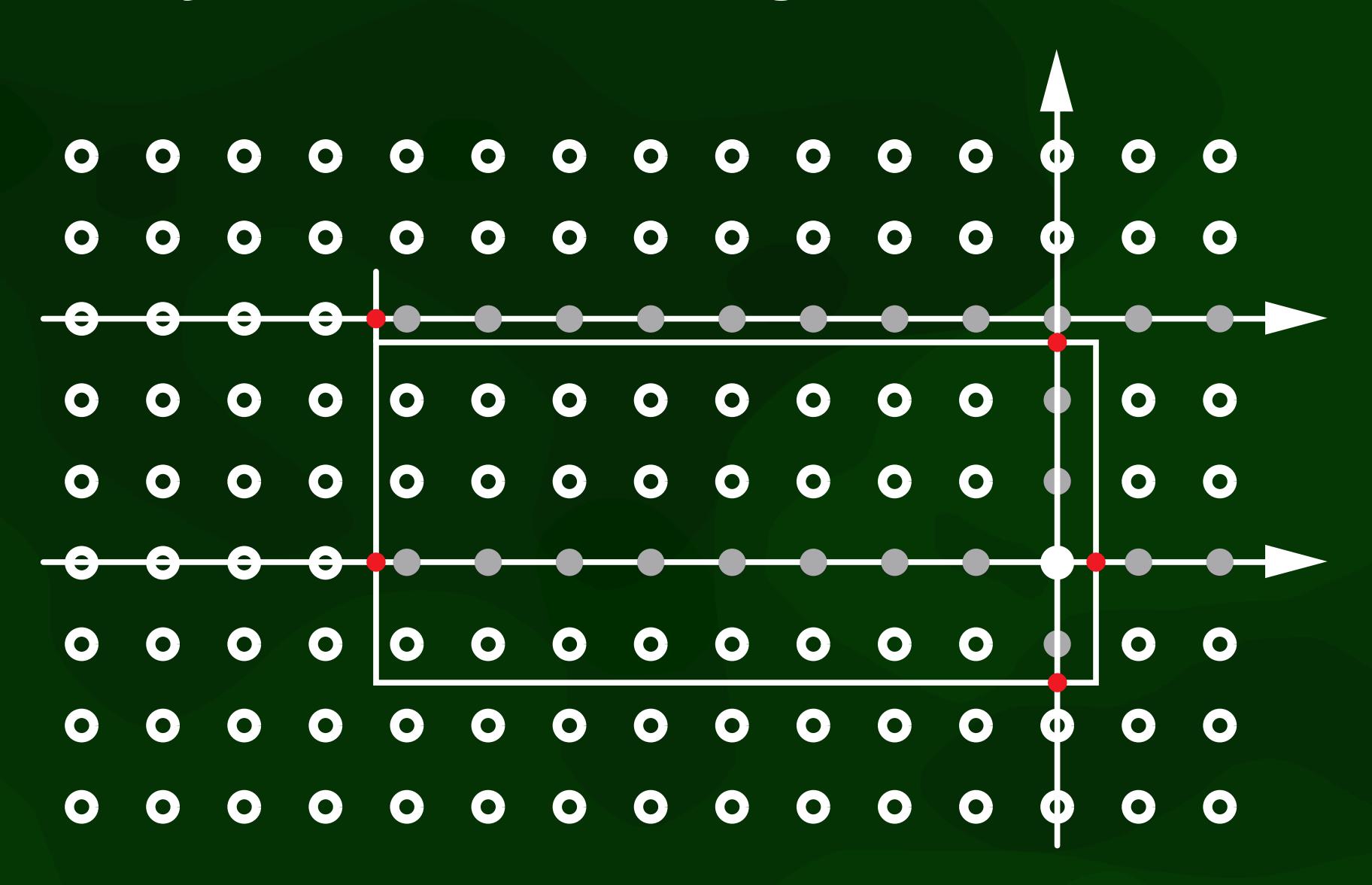
## Voxelisation: gap



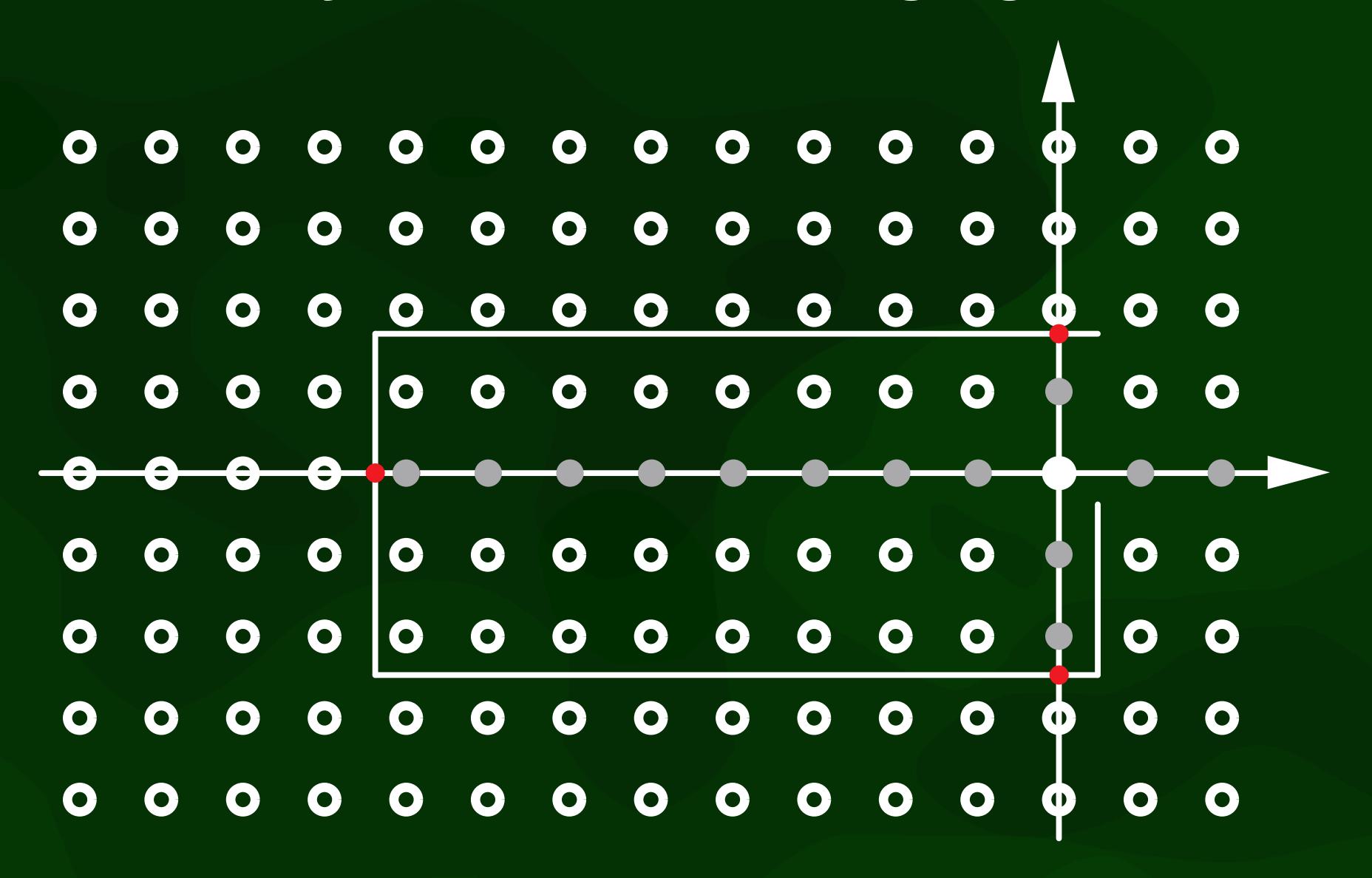
## Voxelisation: shooting rays



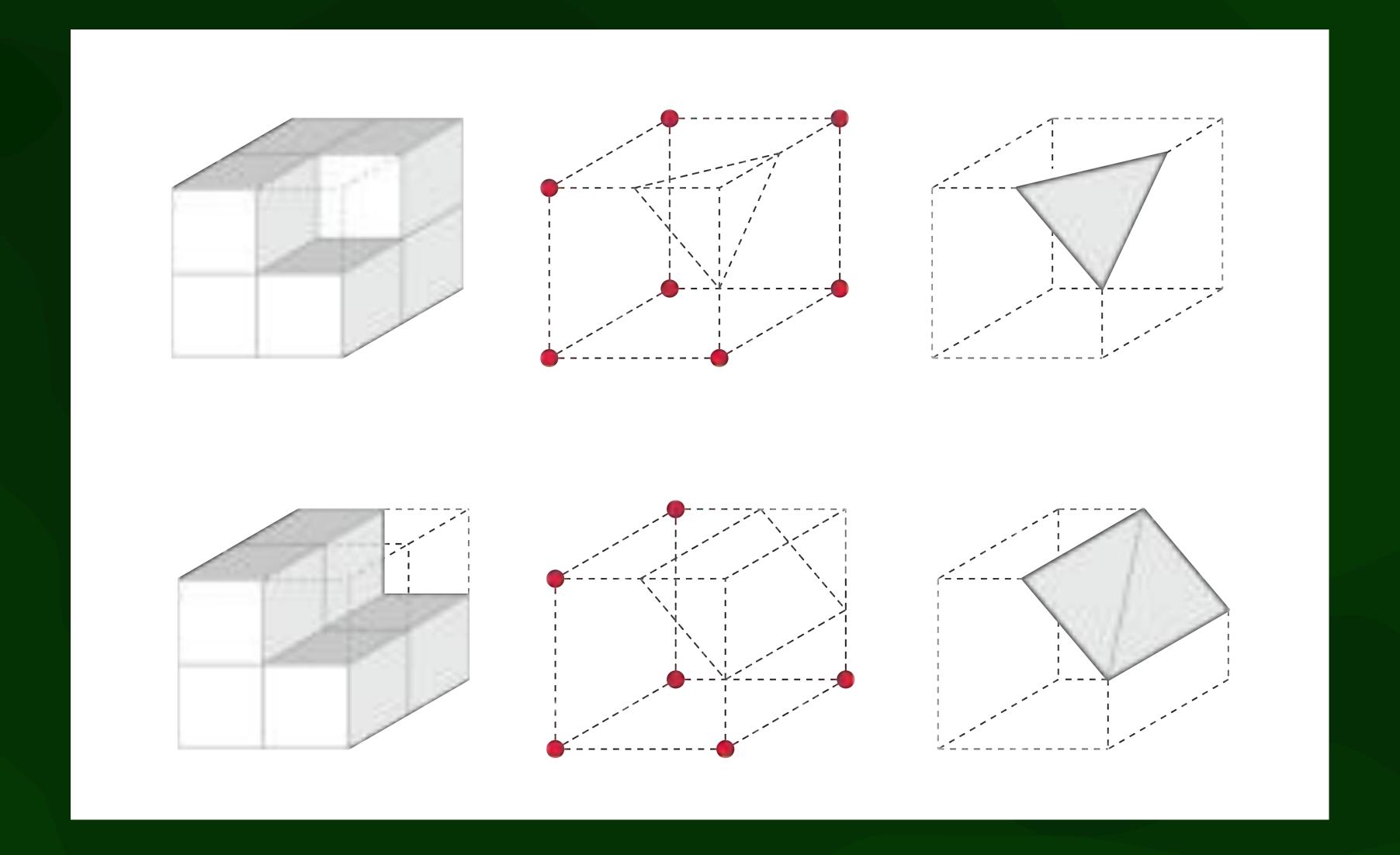
#### Majority counting: overshoot

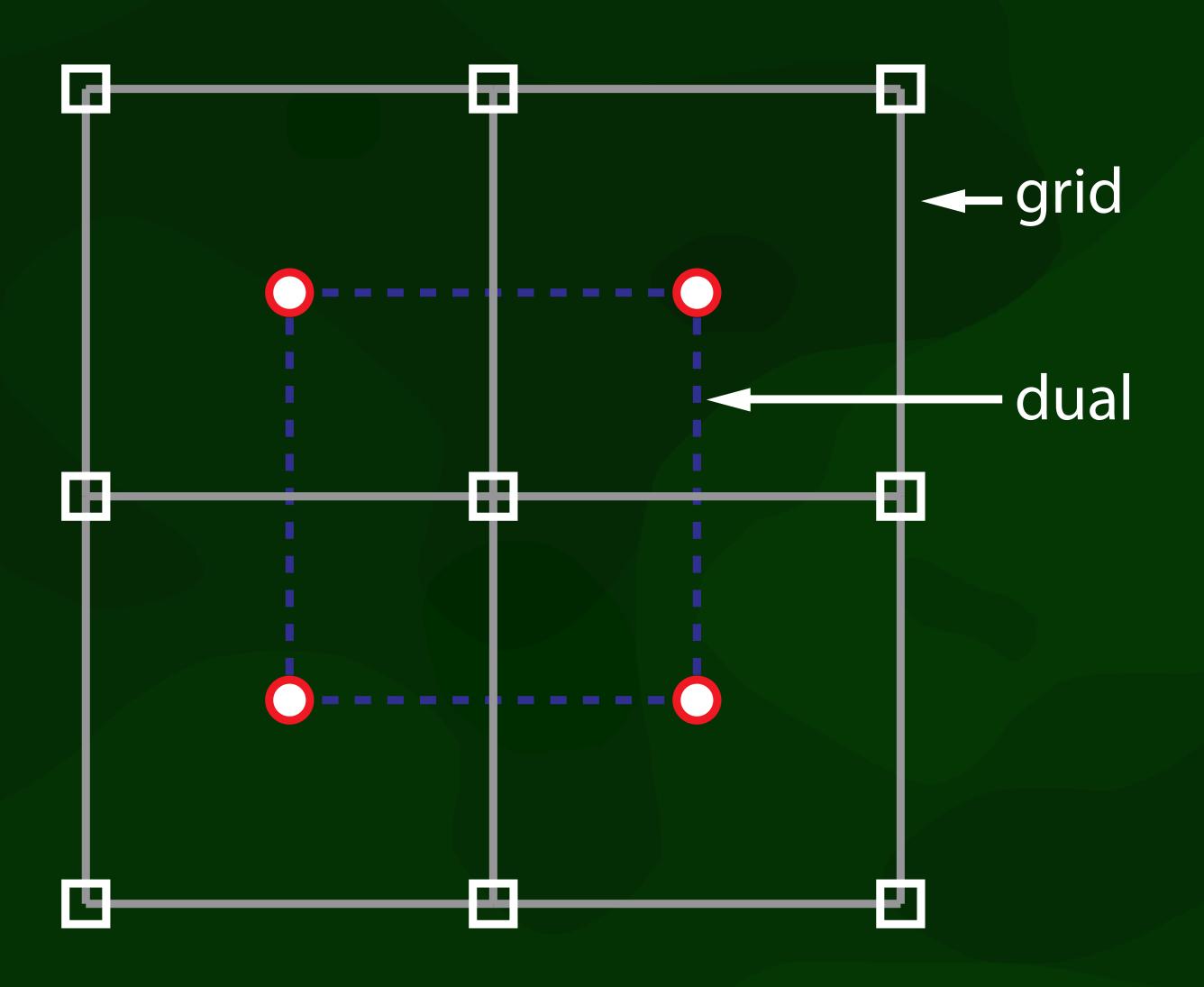


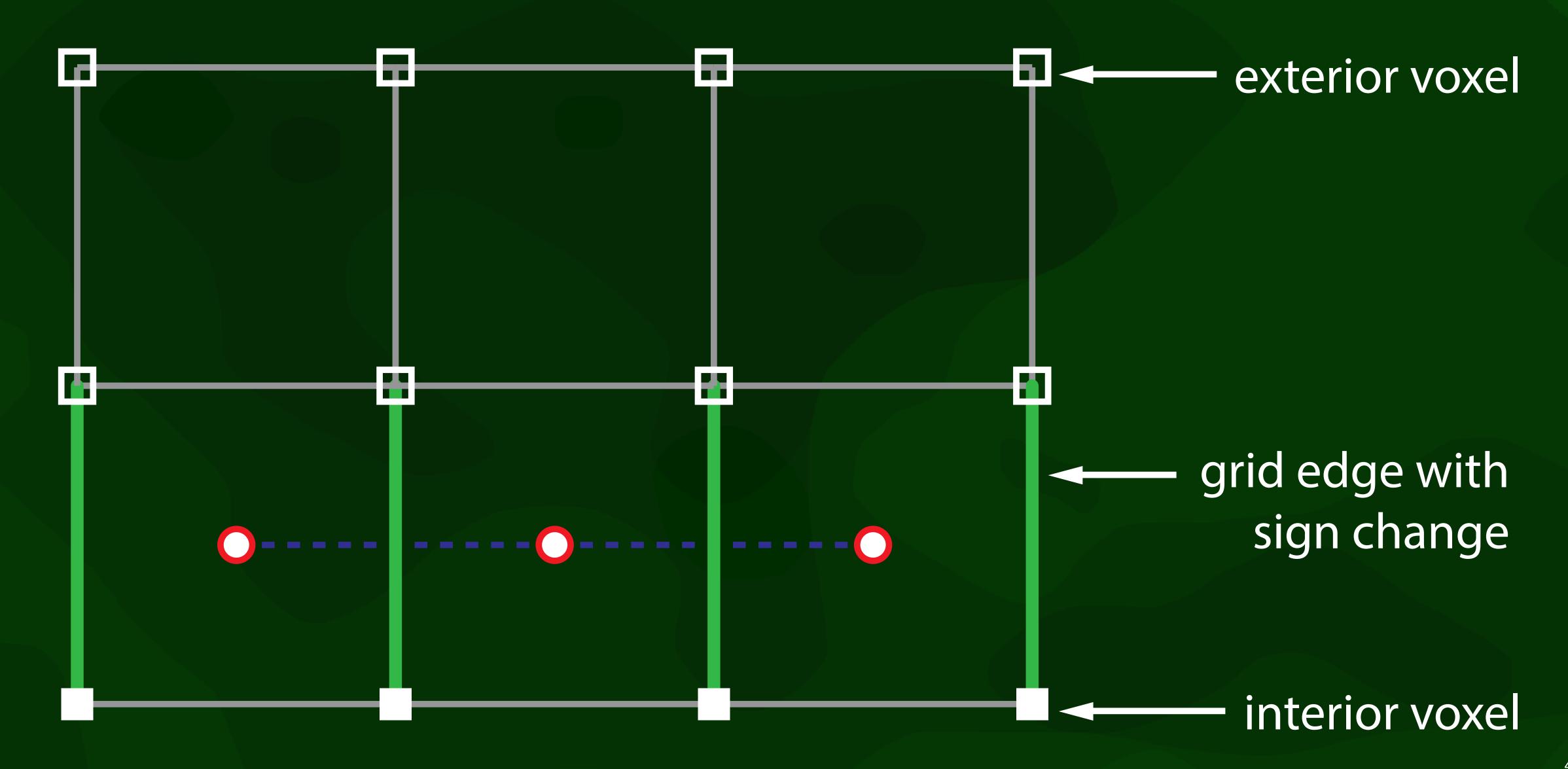
#### Majority counting: gap

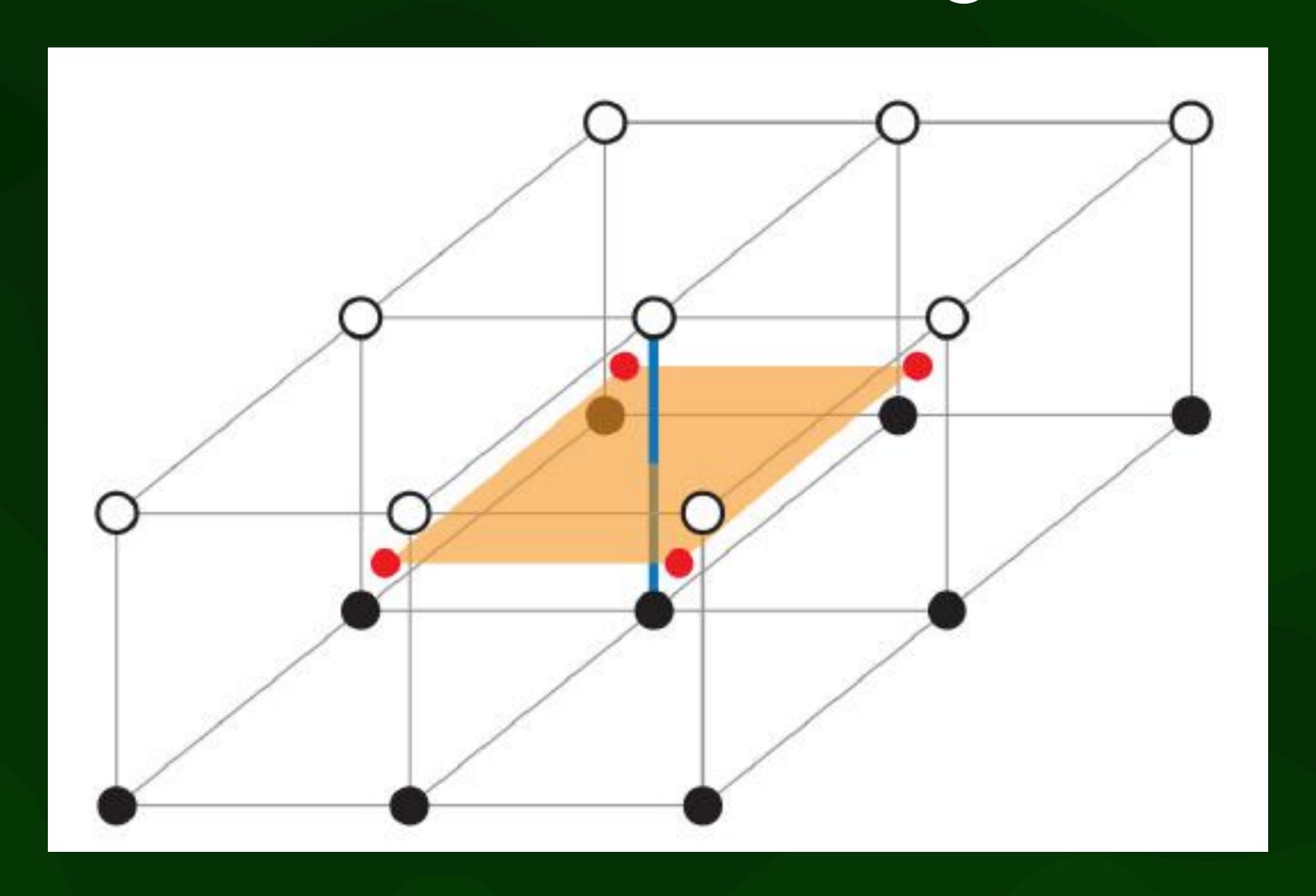


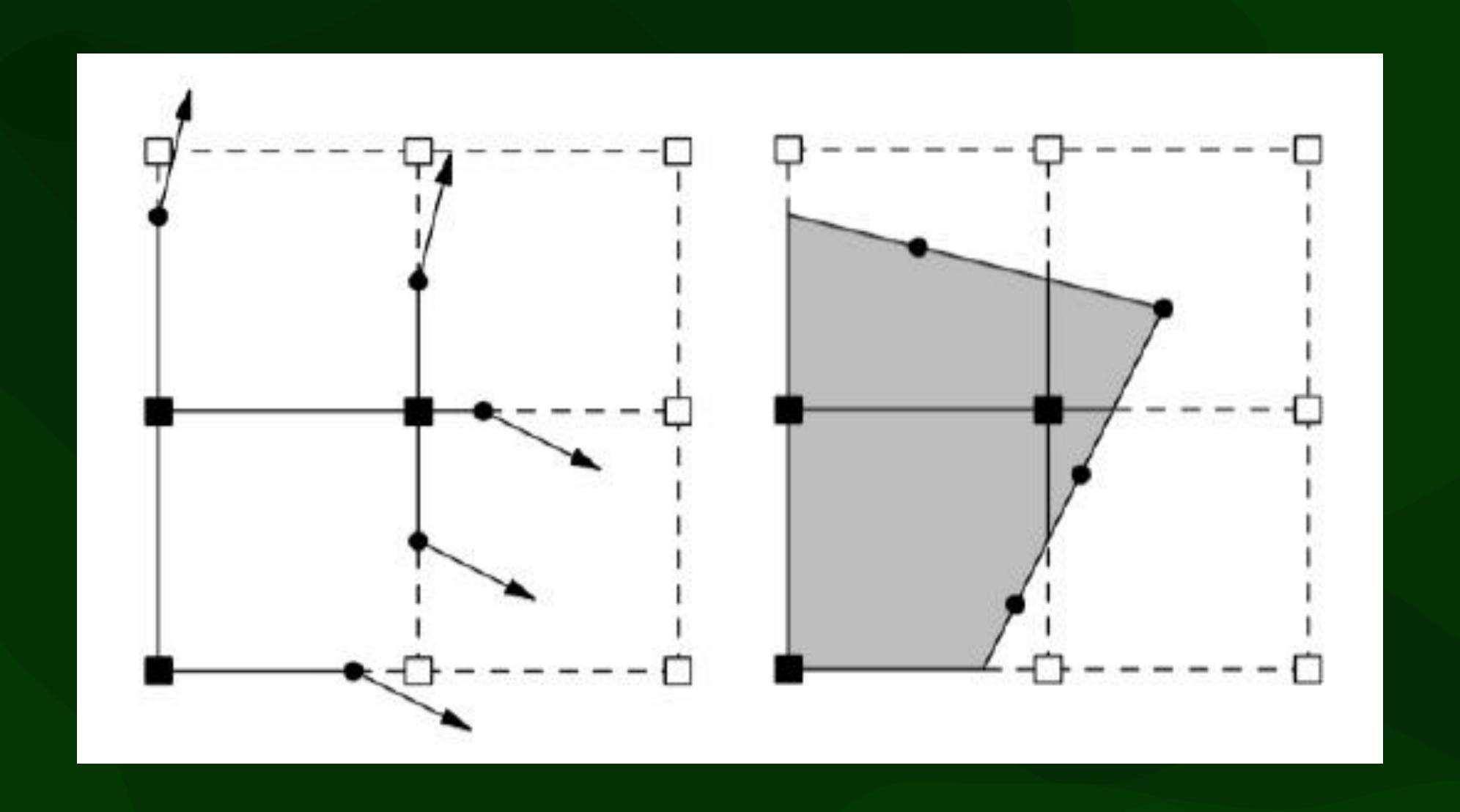
## Marching cubes



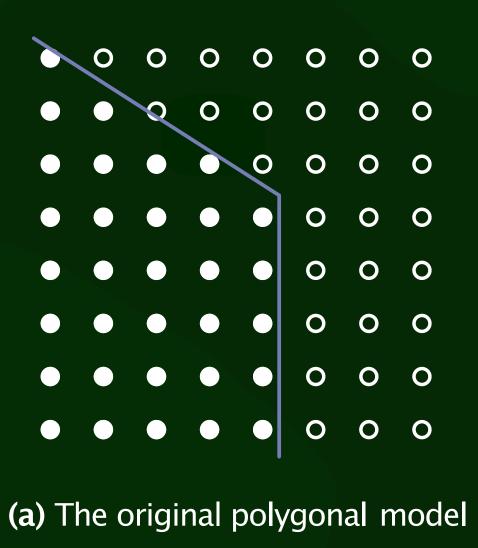


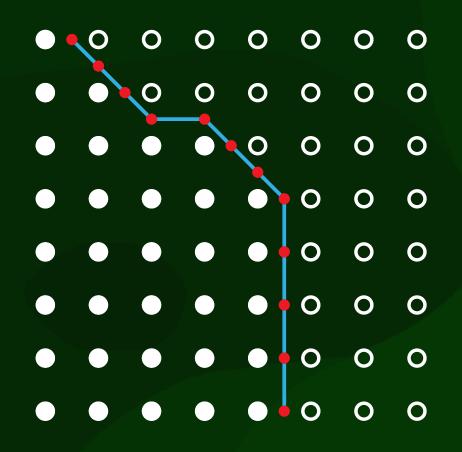






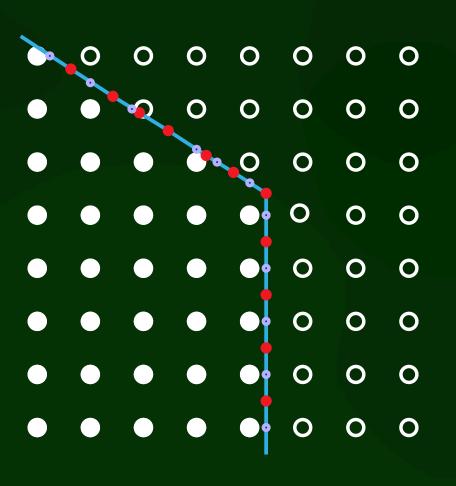
## Full process

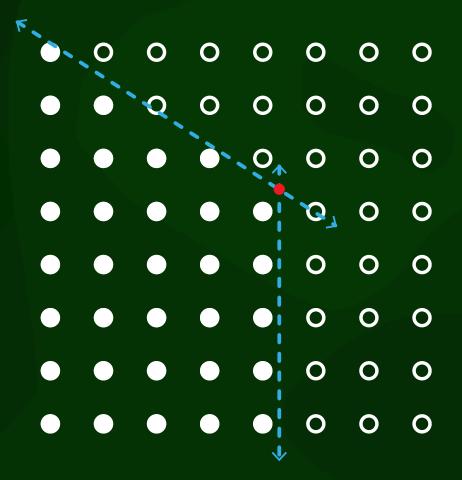






**(b)** Marching Cubes result

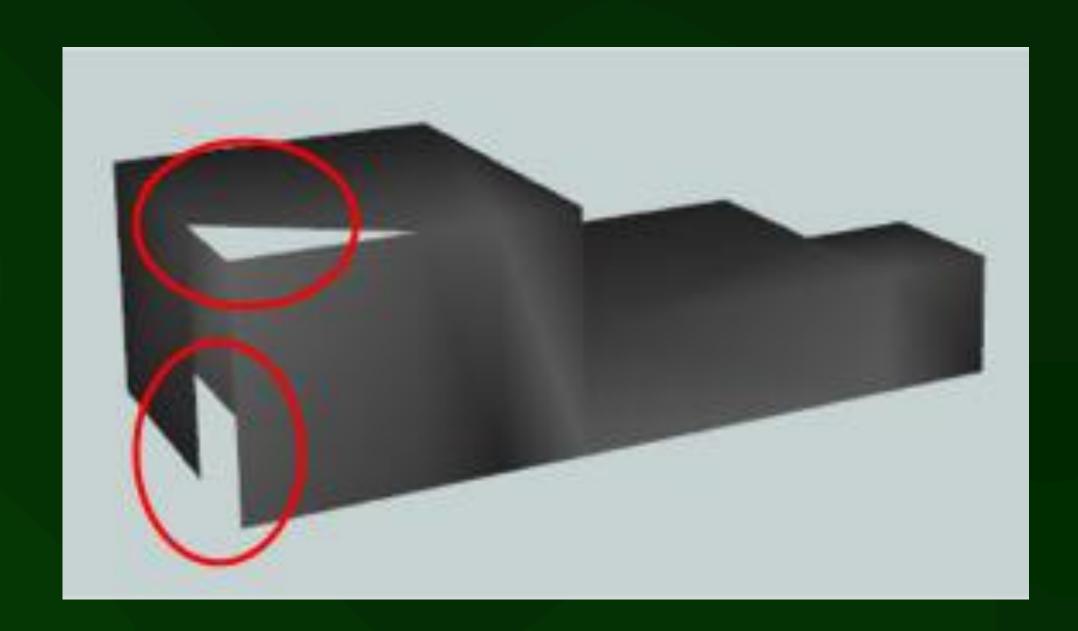


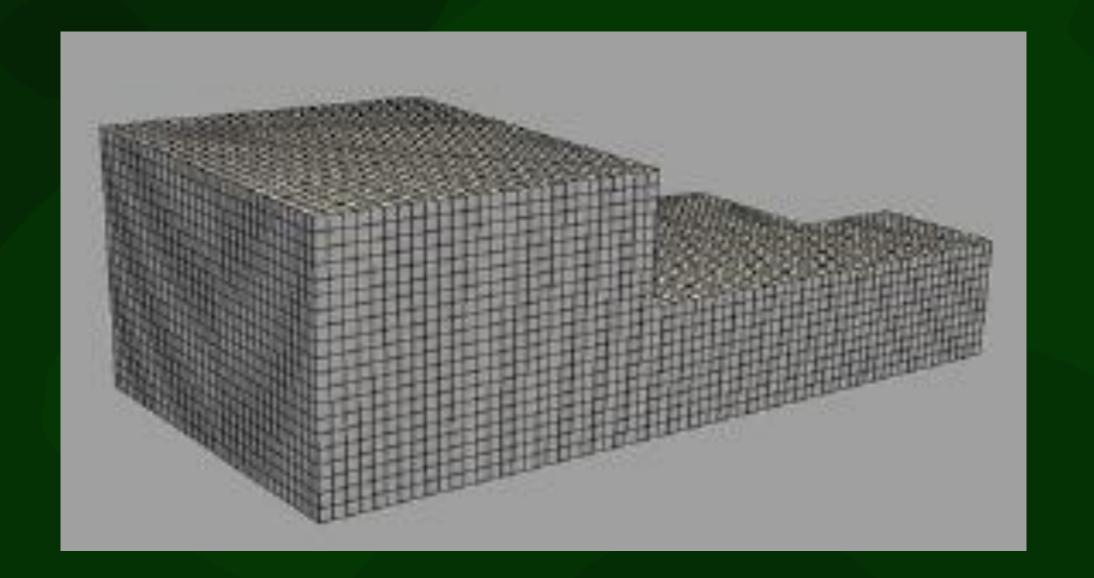


(c) Dual Contouring result

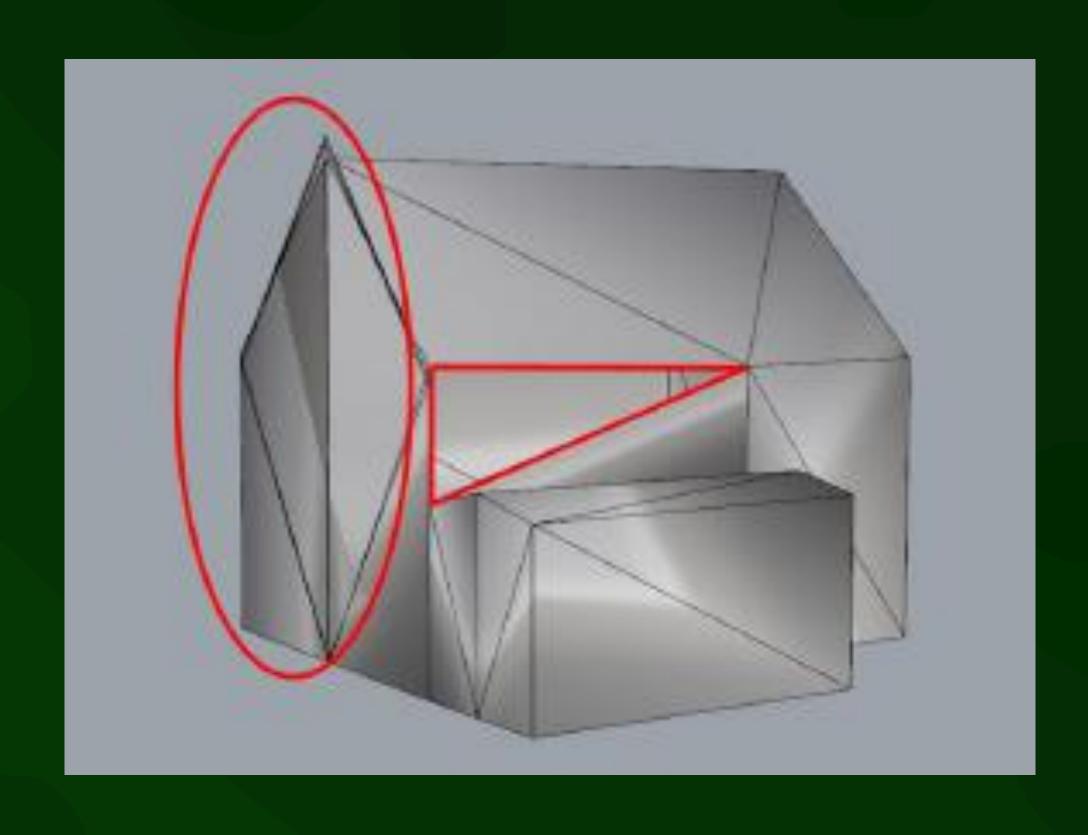
(d) Pressing result

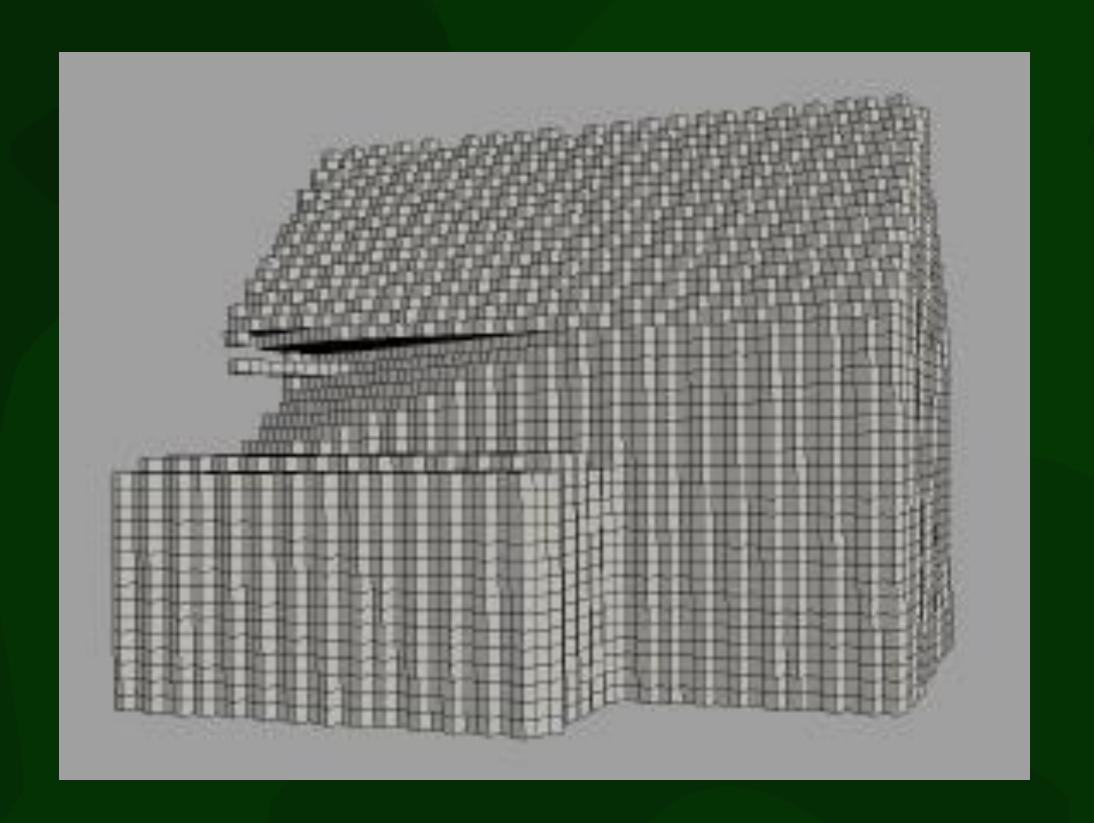
### Results



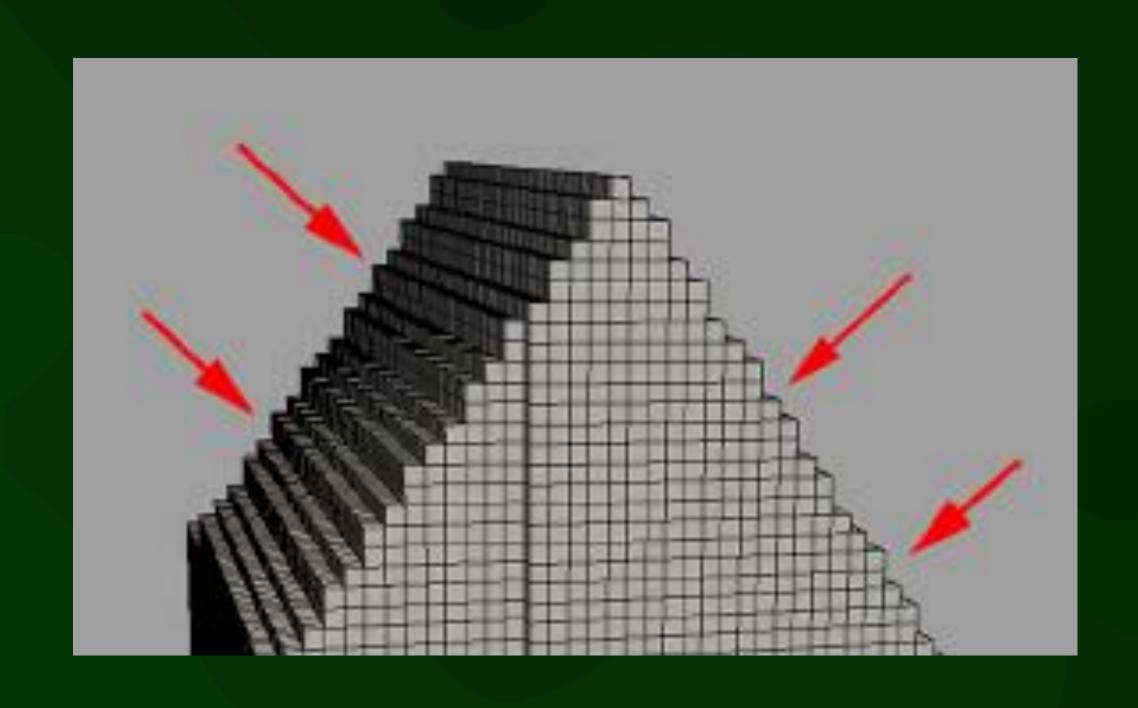


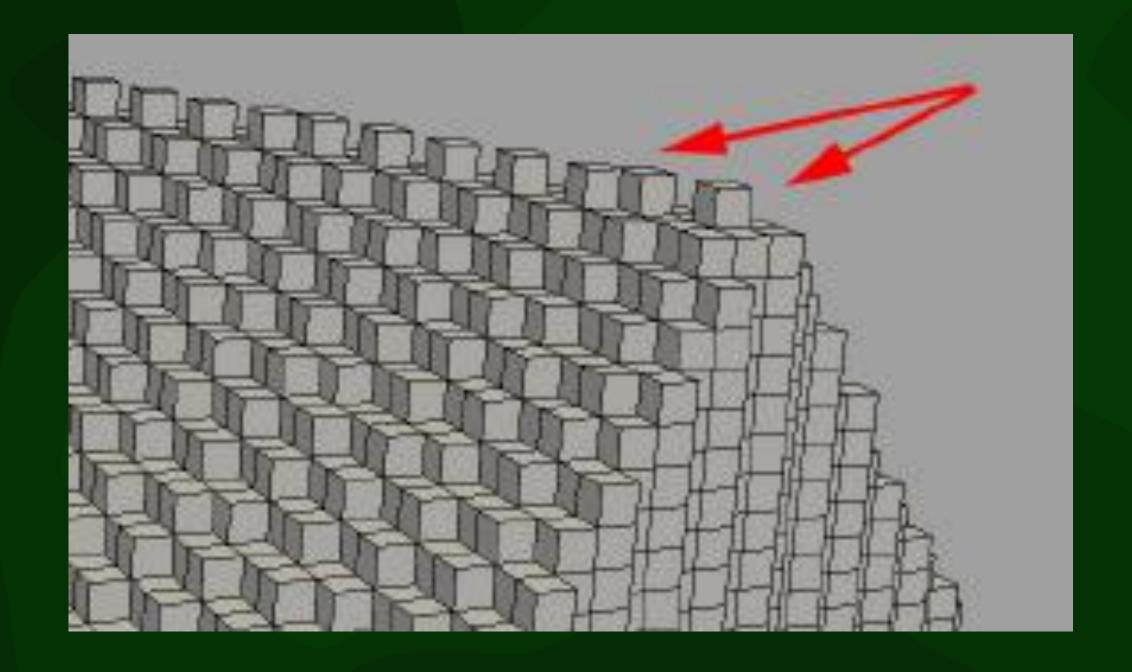
### Results



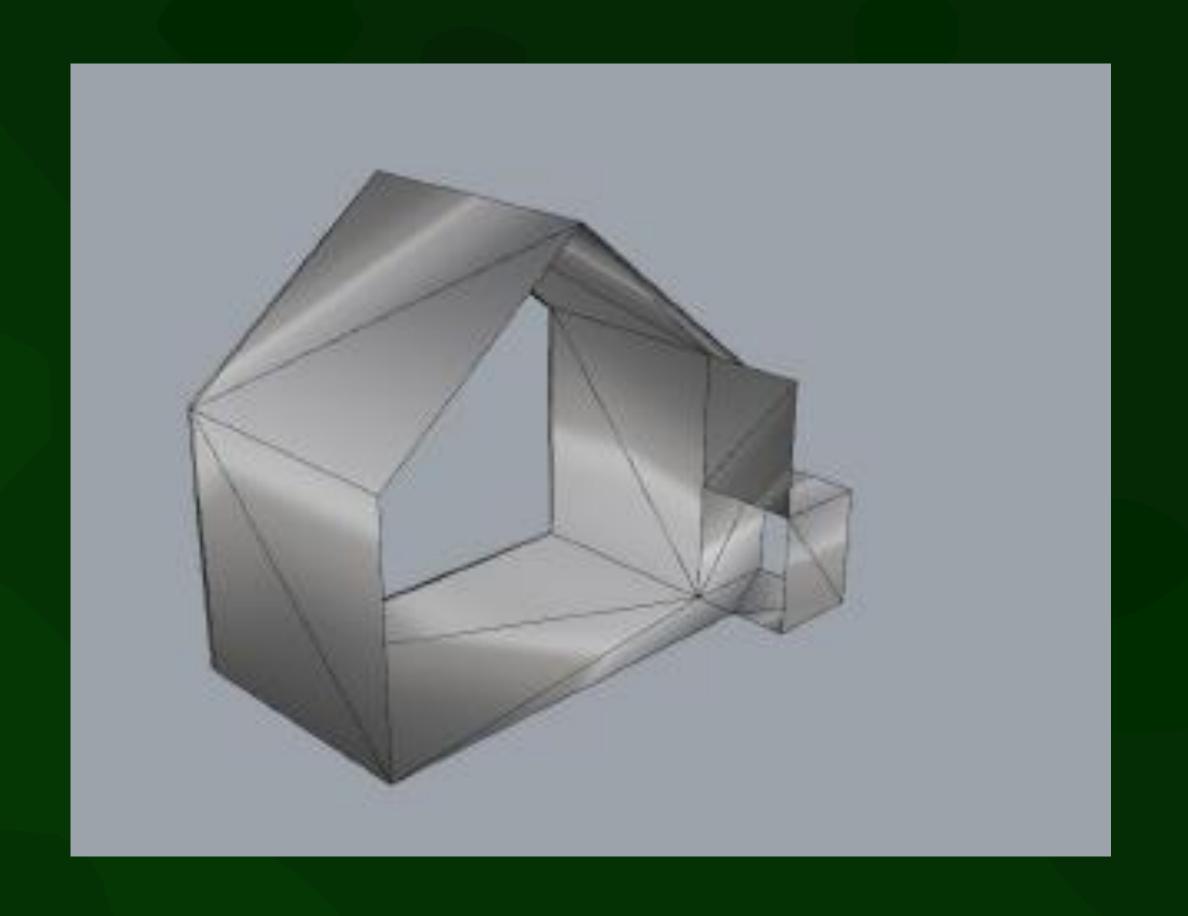


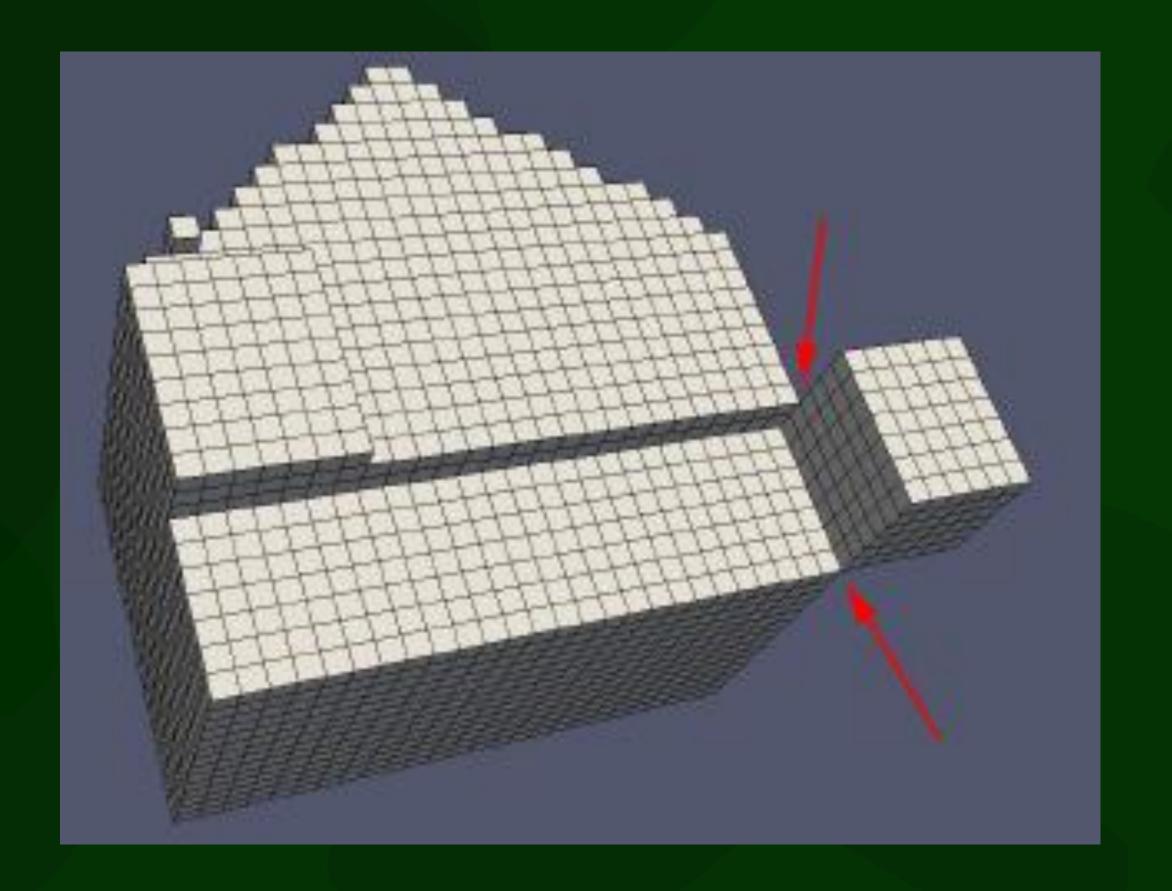
### Artefacts



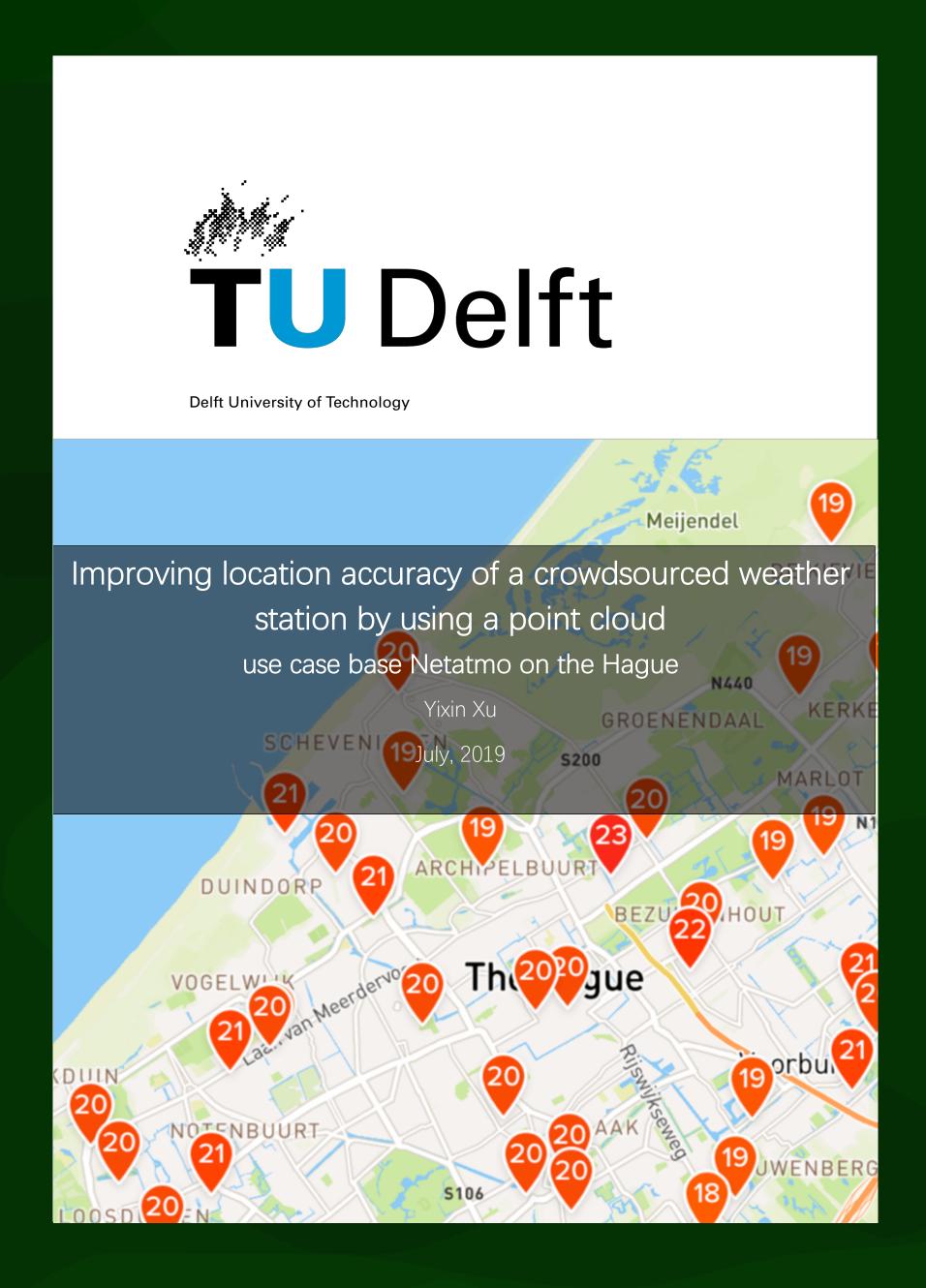


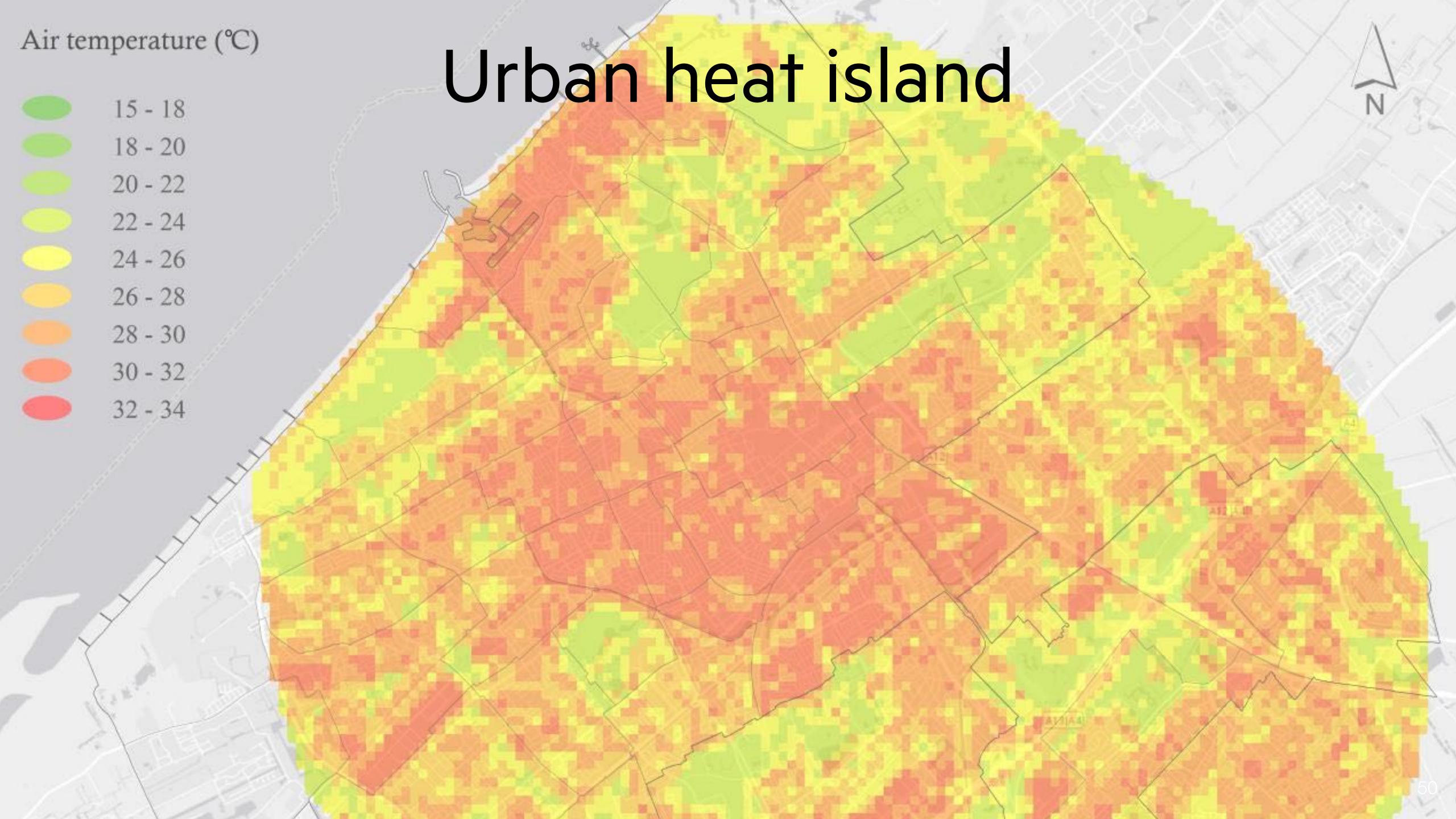
### Results





- Motivation: improving the accuracy of the location of personal weather stations for urban heat island research
- Generate potential locations
- Evaluate them through skyview + solar modelling





### Traditional weather stations



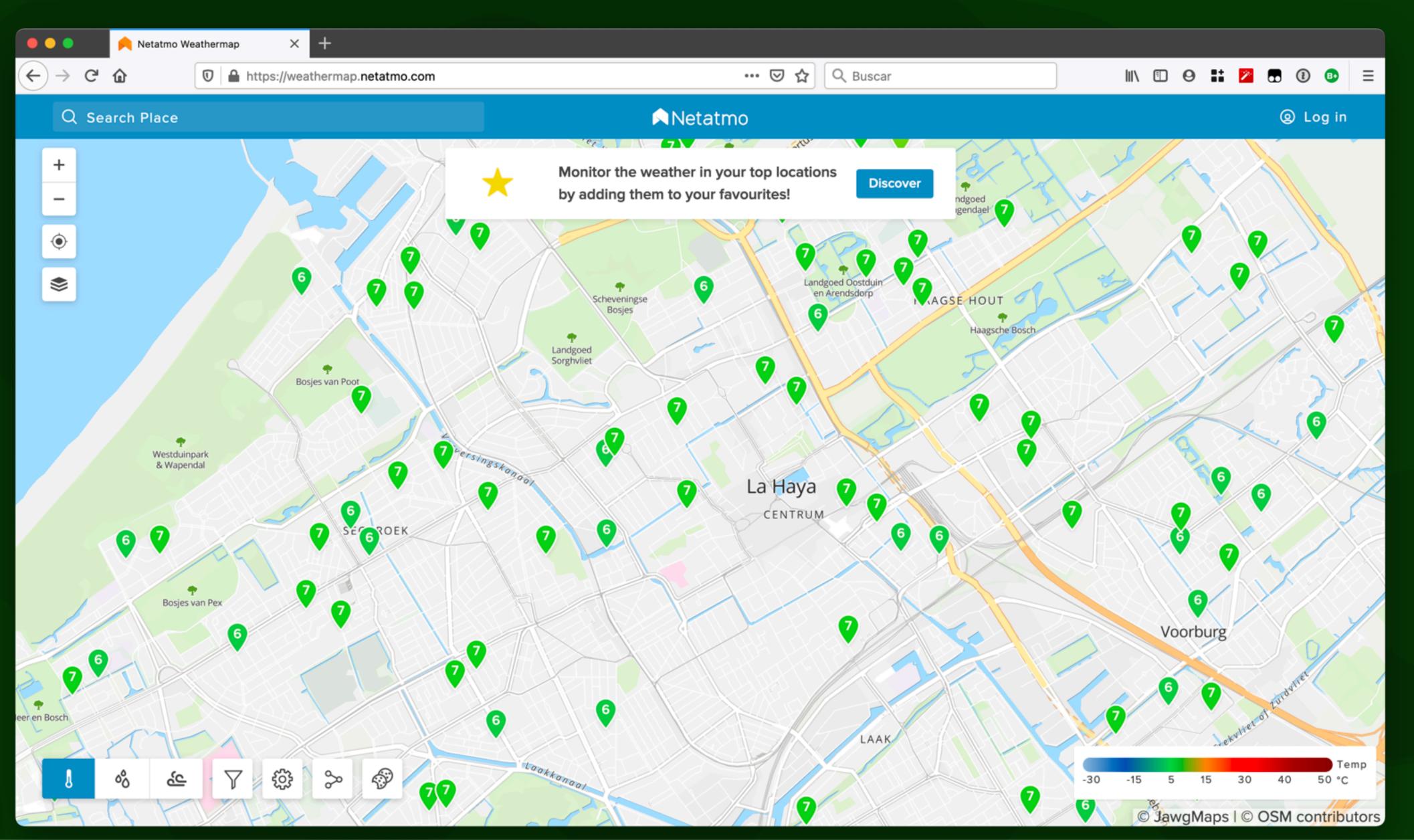
#### Personal weather stations



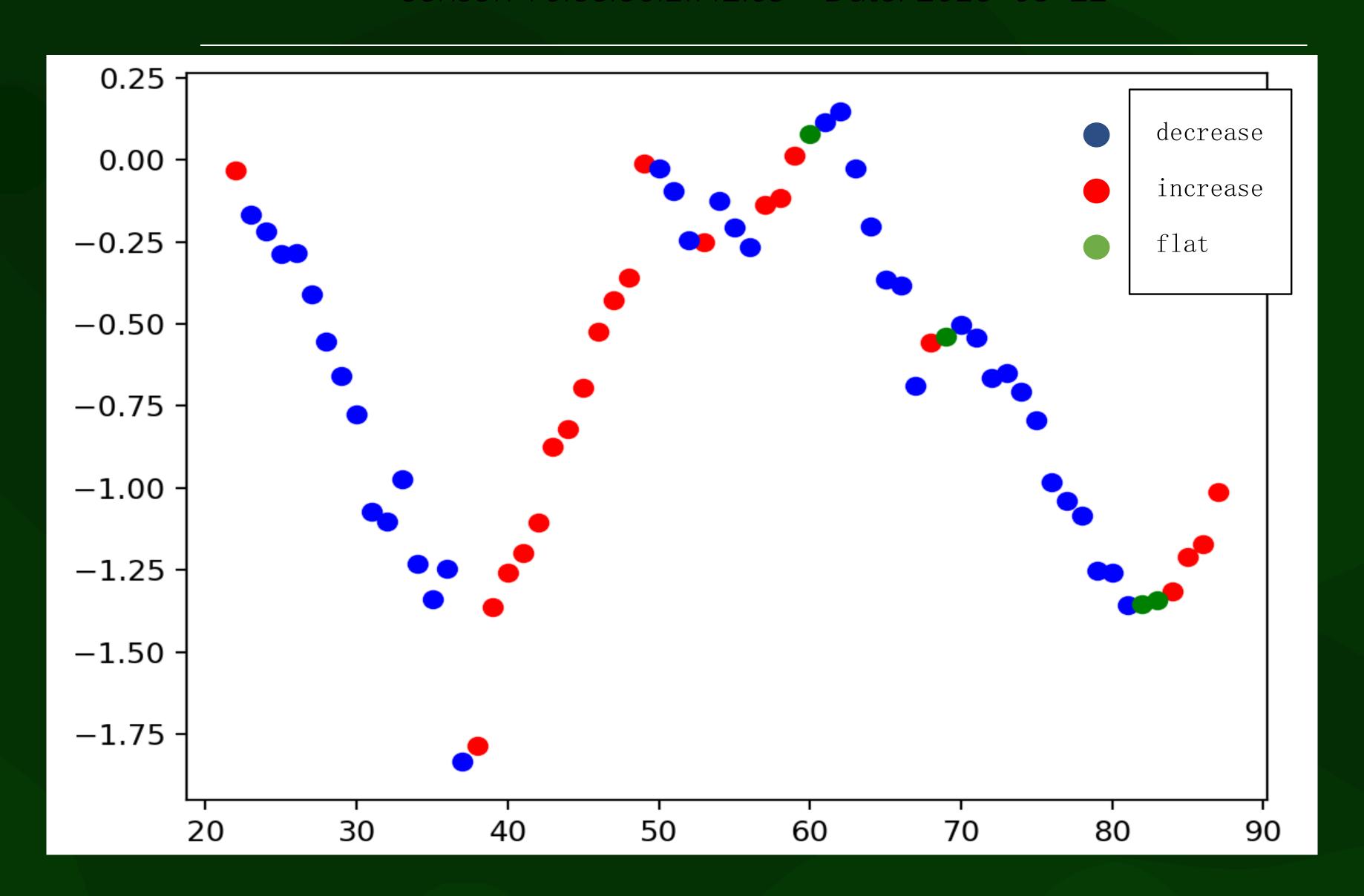




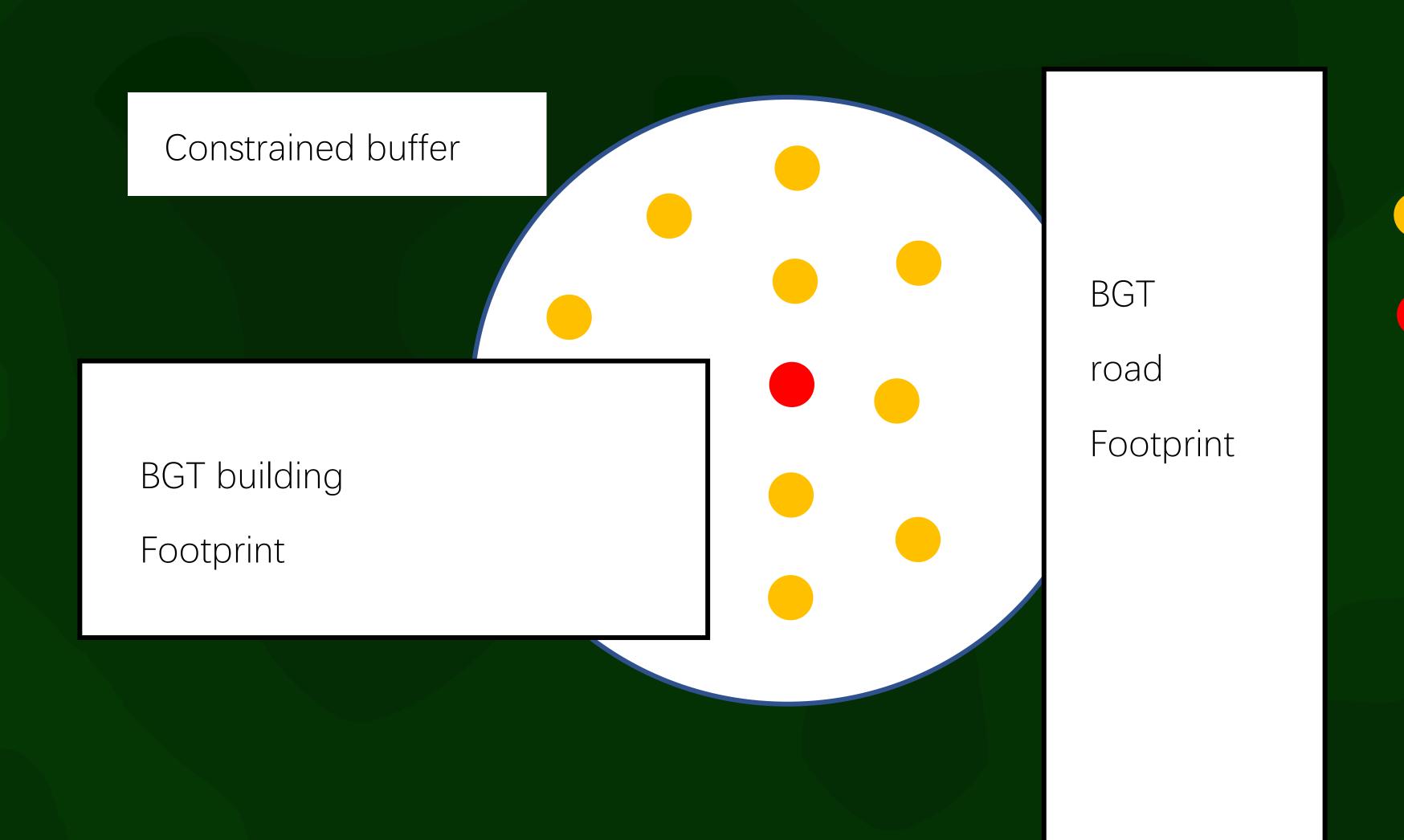
#### Crowdsourced weather data



#### Behaviour Sensor Peles 142 O Urte: 2018-05-22



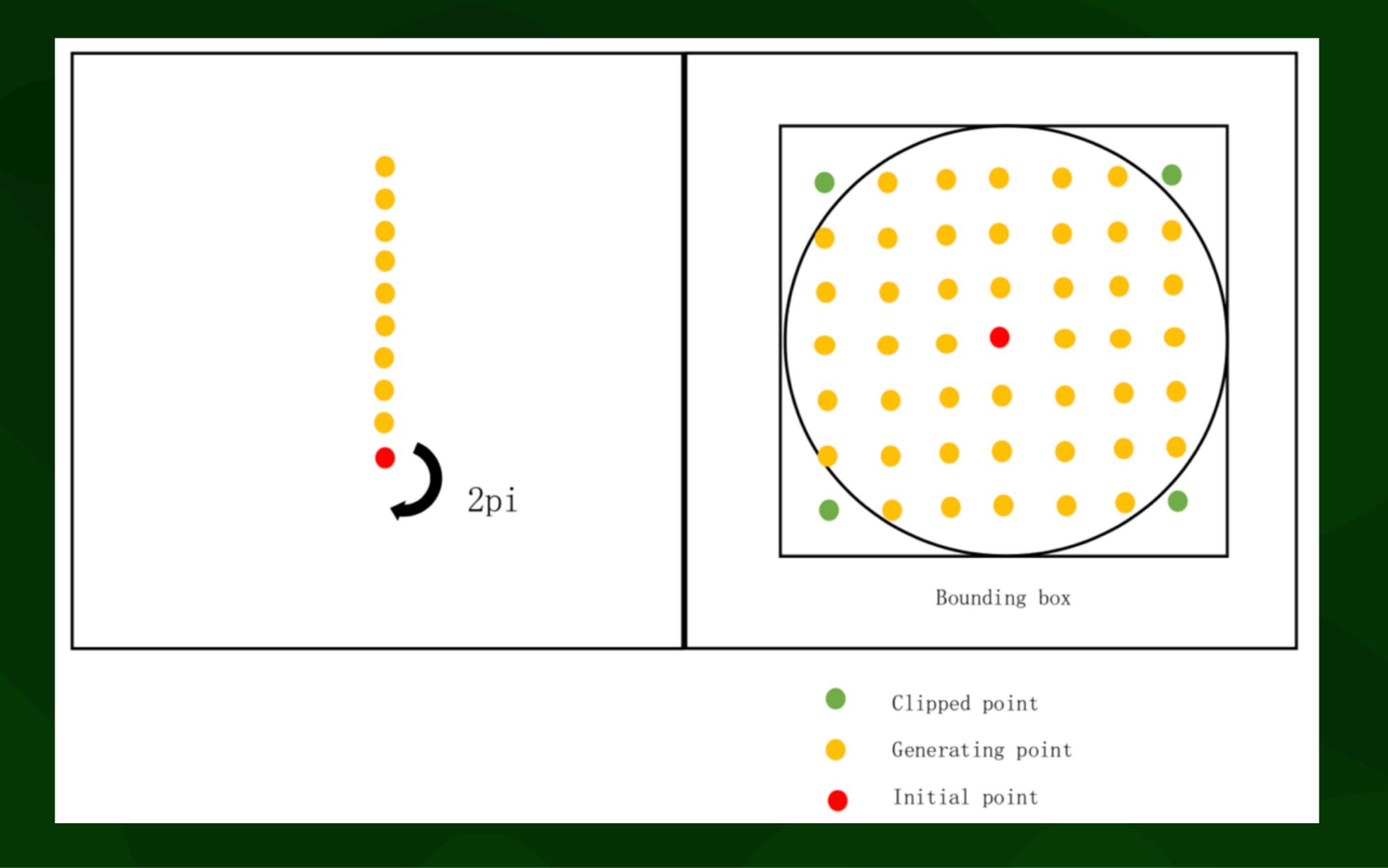
#### Potential locations



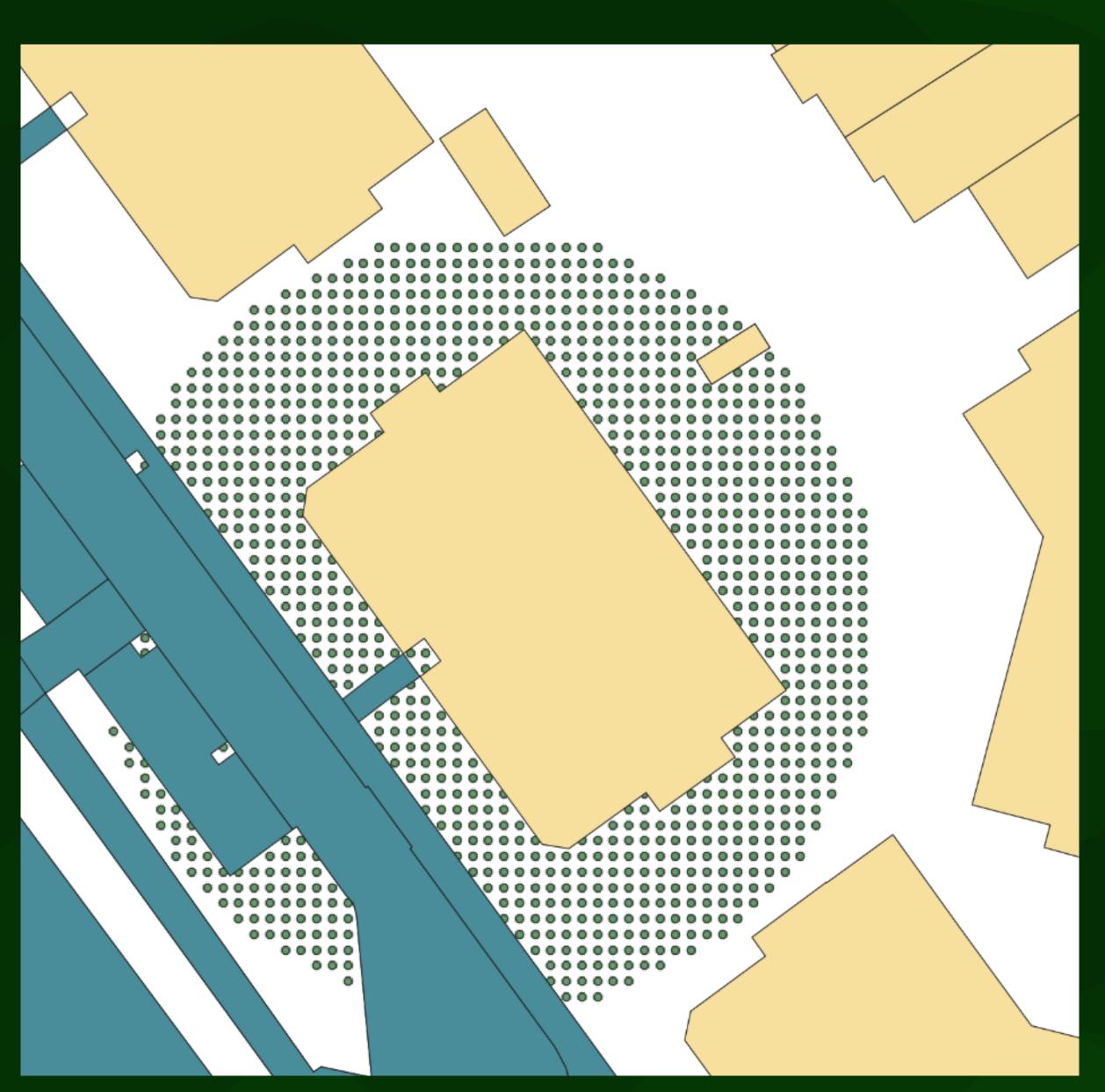
Potential location

Given location

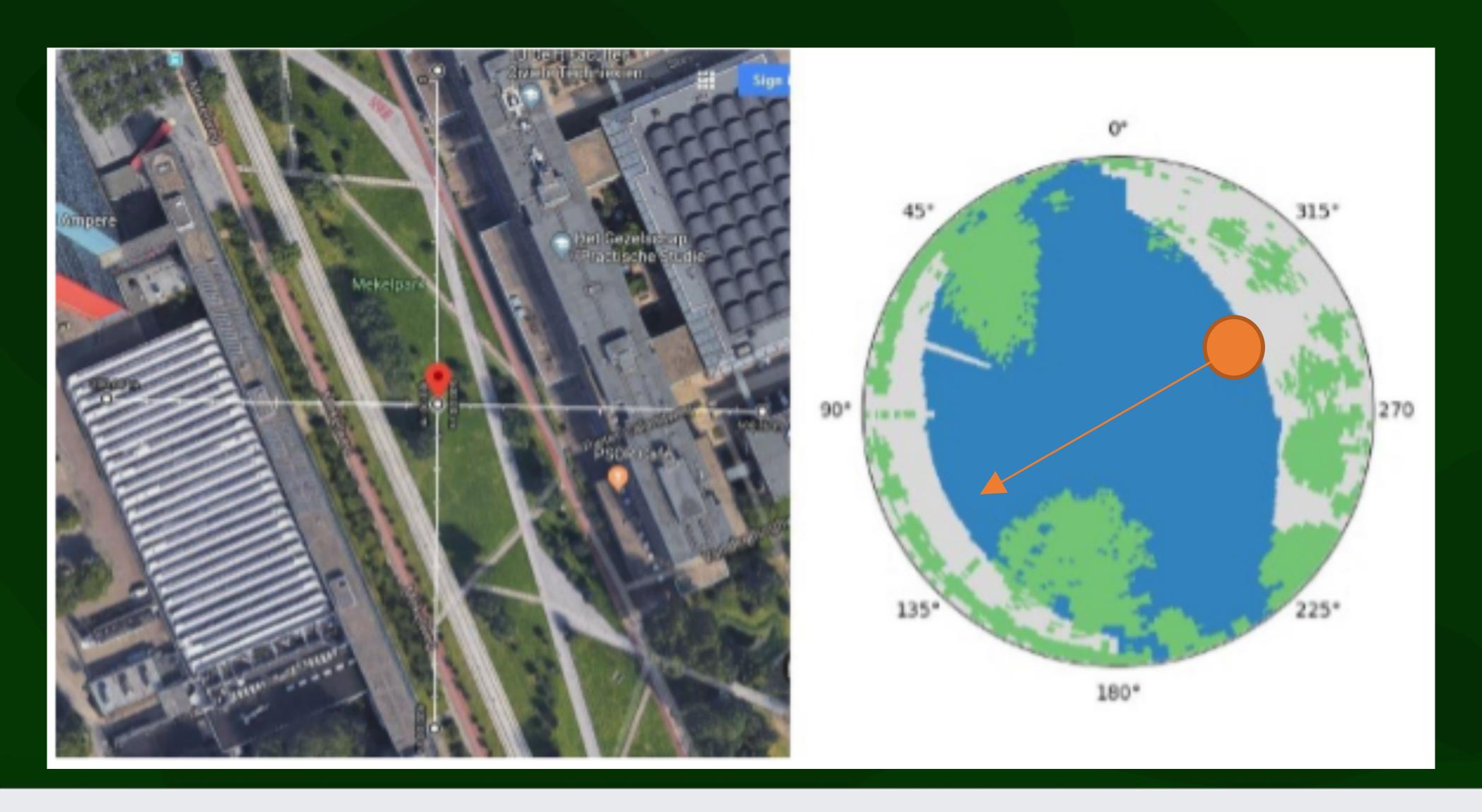
#### Potential locations



#### Potential locations



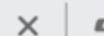
## Skyview computation







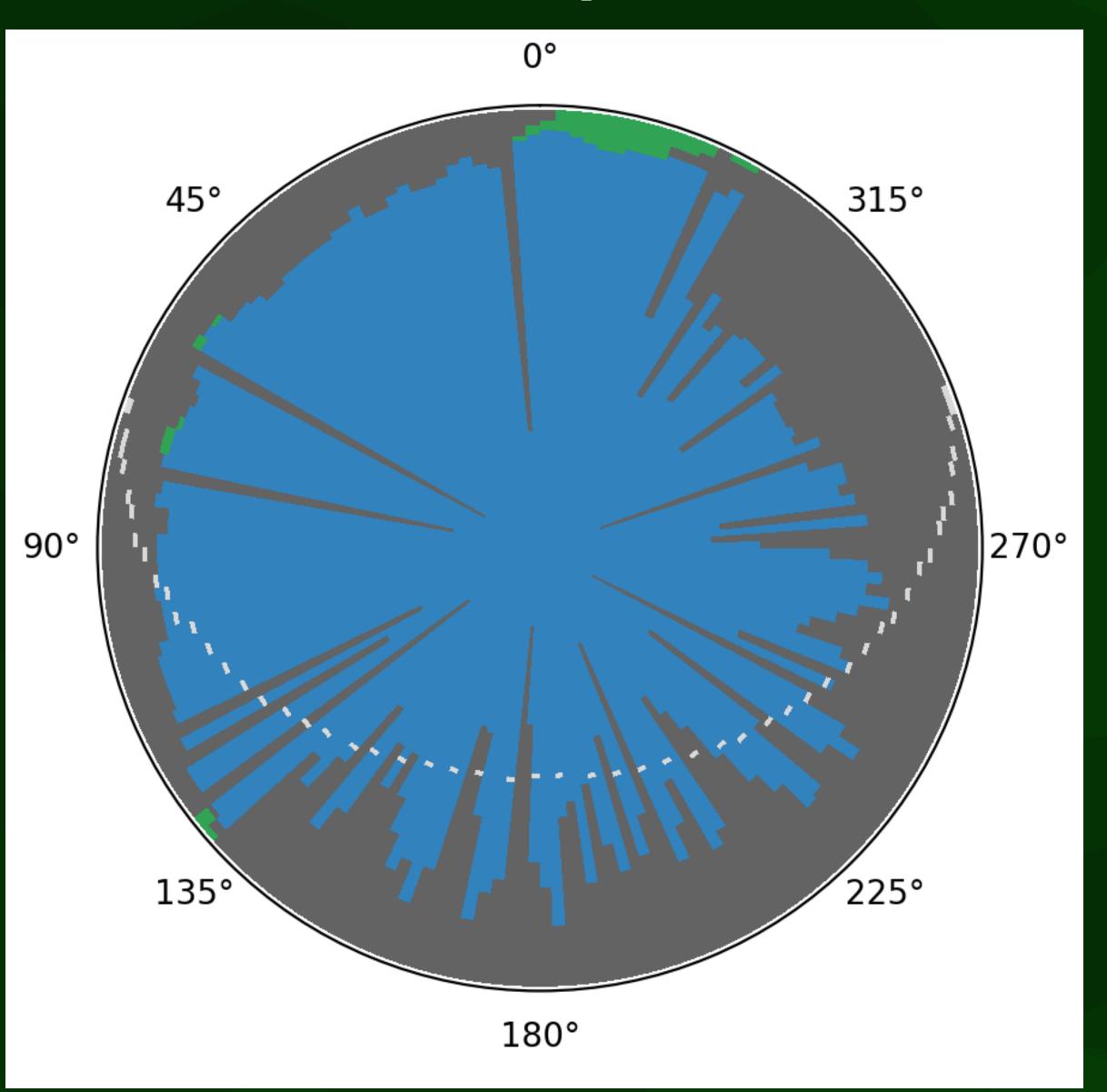




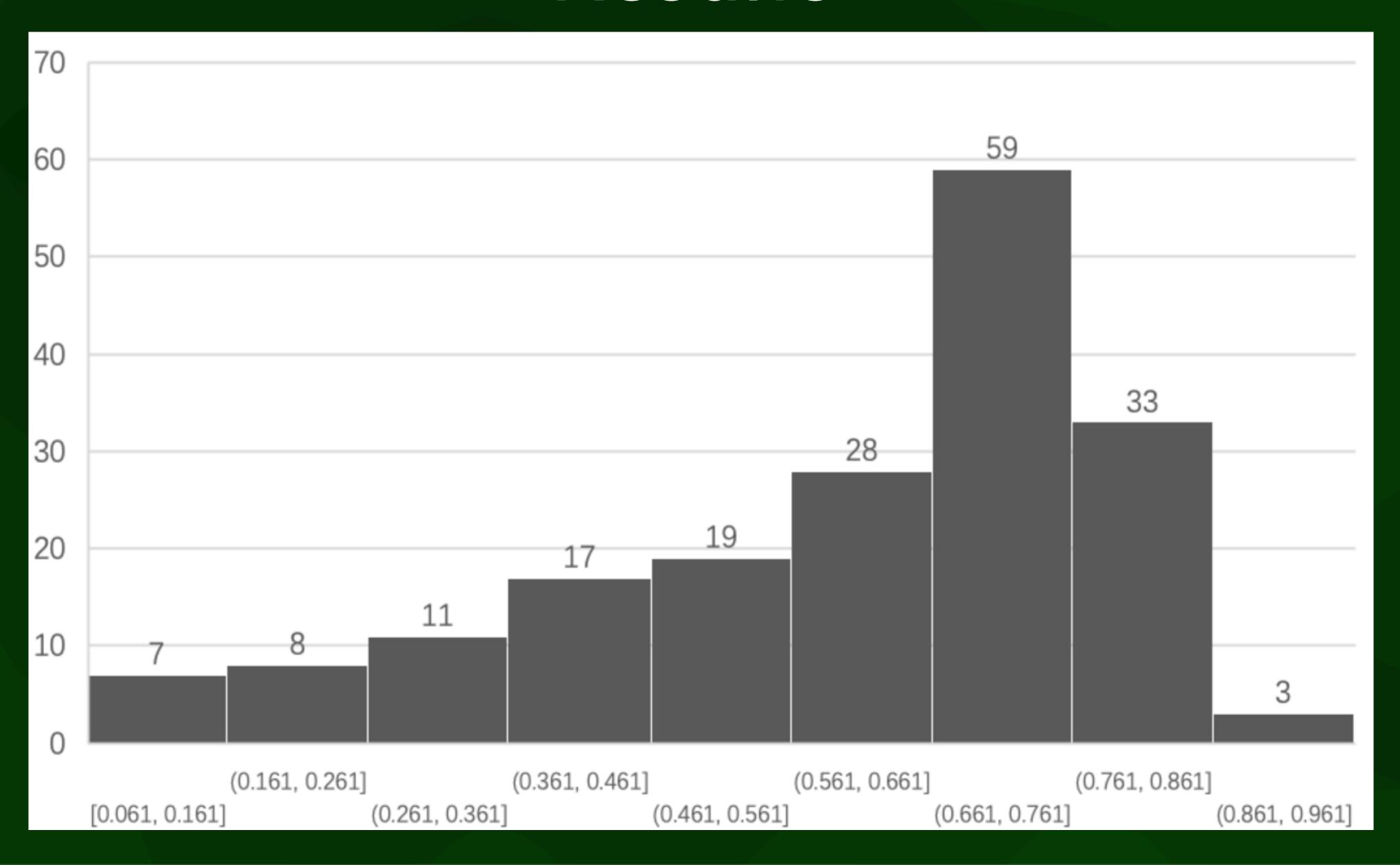




## Analysis



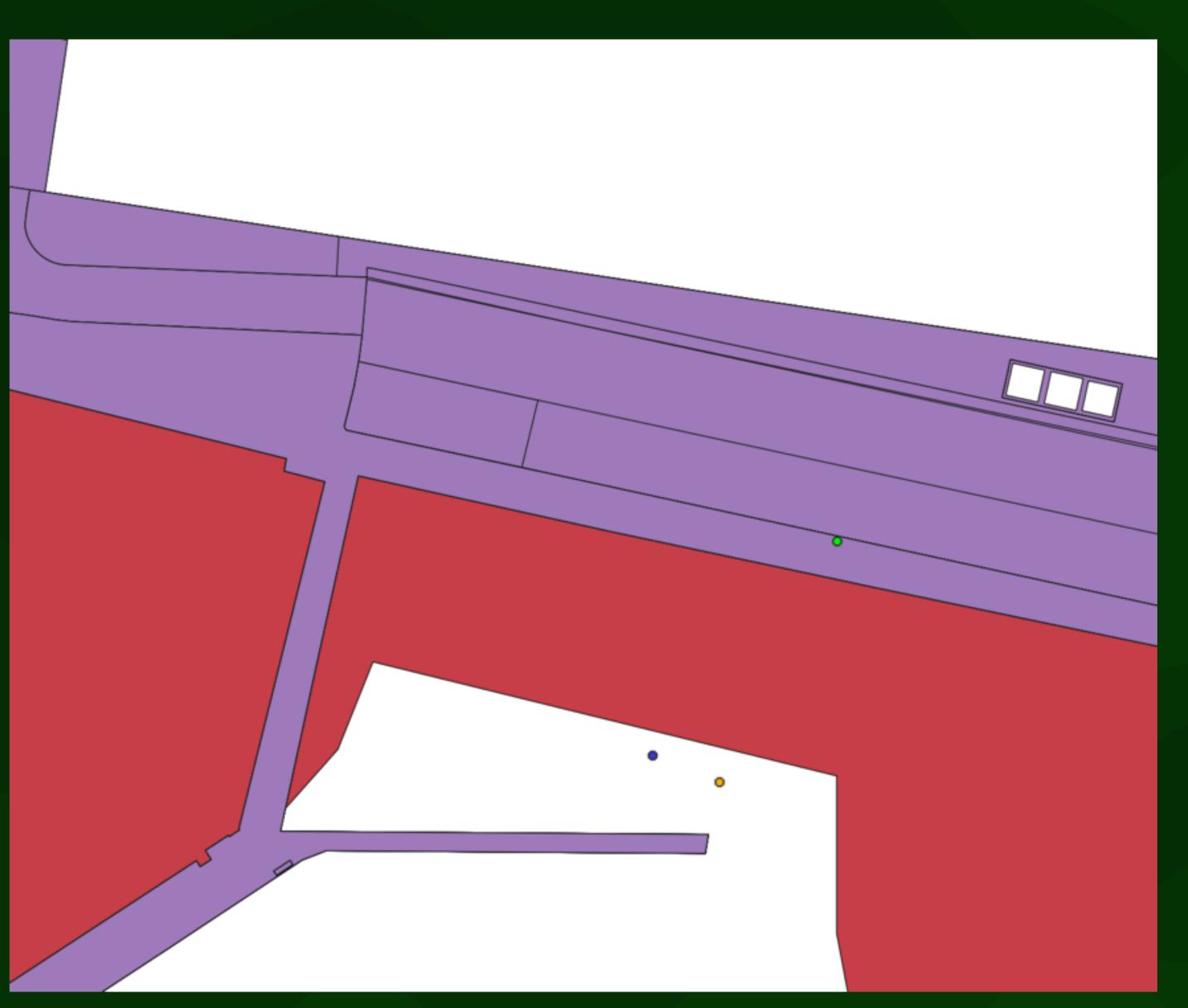
#### Results



## Experiment



# Experiment



#### Recommendations

- GEO5014: Geomatics as support for energy applications
- GEO5015: Modelling wind and dispersion in urban environments
- Your own MSc thesis

#### Sources of images

- [2-6]: Filip Biljecki (paper on application of 3D city models and PhD thesis)
- [9-20]: Roeland Boeters (MSc thesis and related paper)
- [21-29]: Sjors Donkers (MSc thesis and related paper)
- [30-48]: Damien Mulder (MSc thesis)
- [49, 51-62]: Yixin Xu (MSc thesis)
- [50]: Anna-Maria Ntarladima (MSc thesis)