

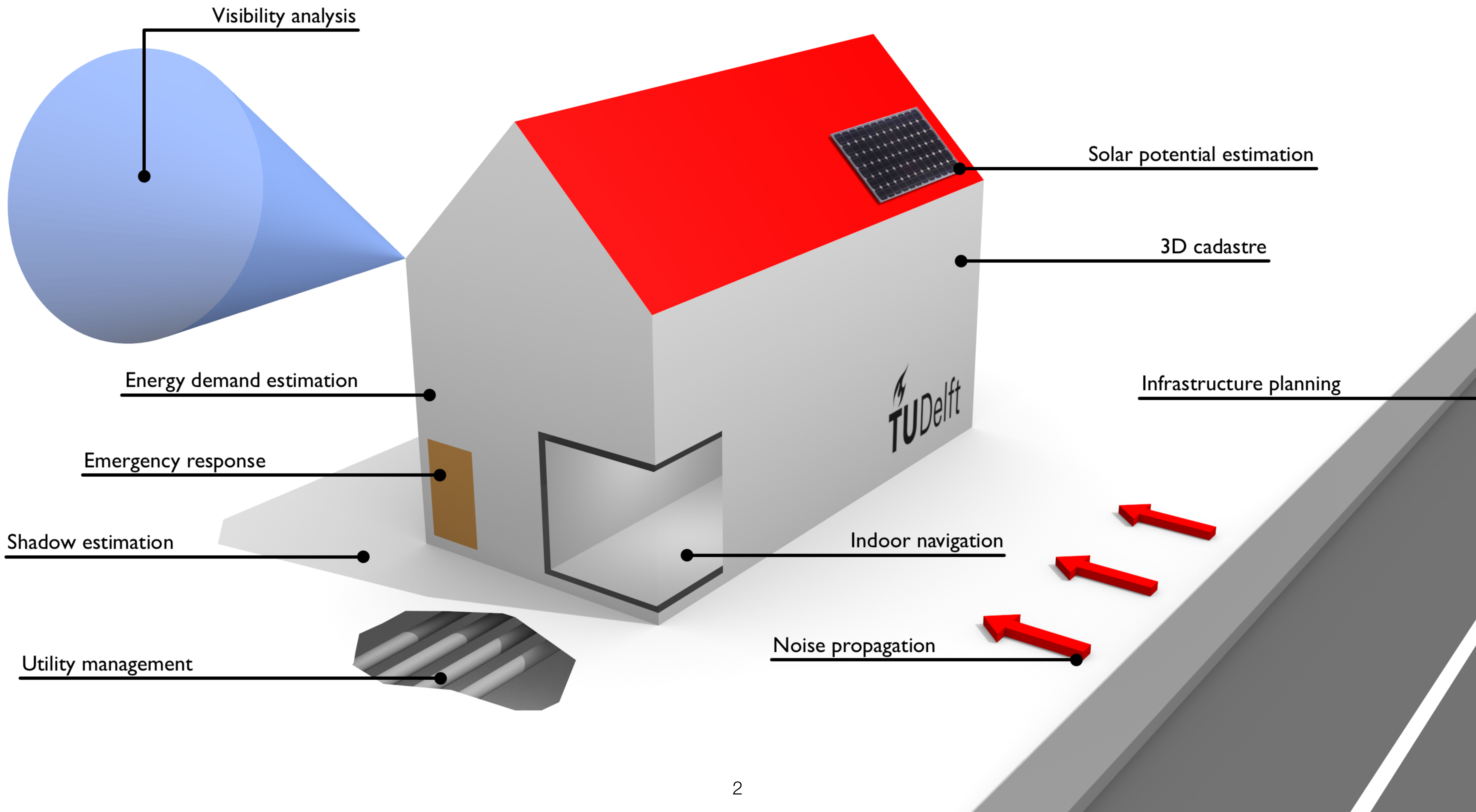
Applications of 3D modelling of the built environment

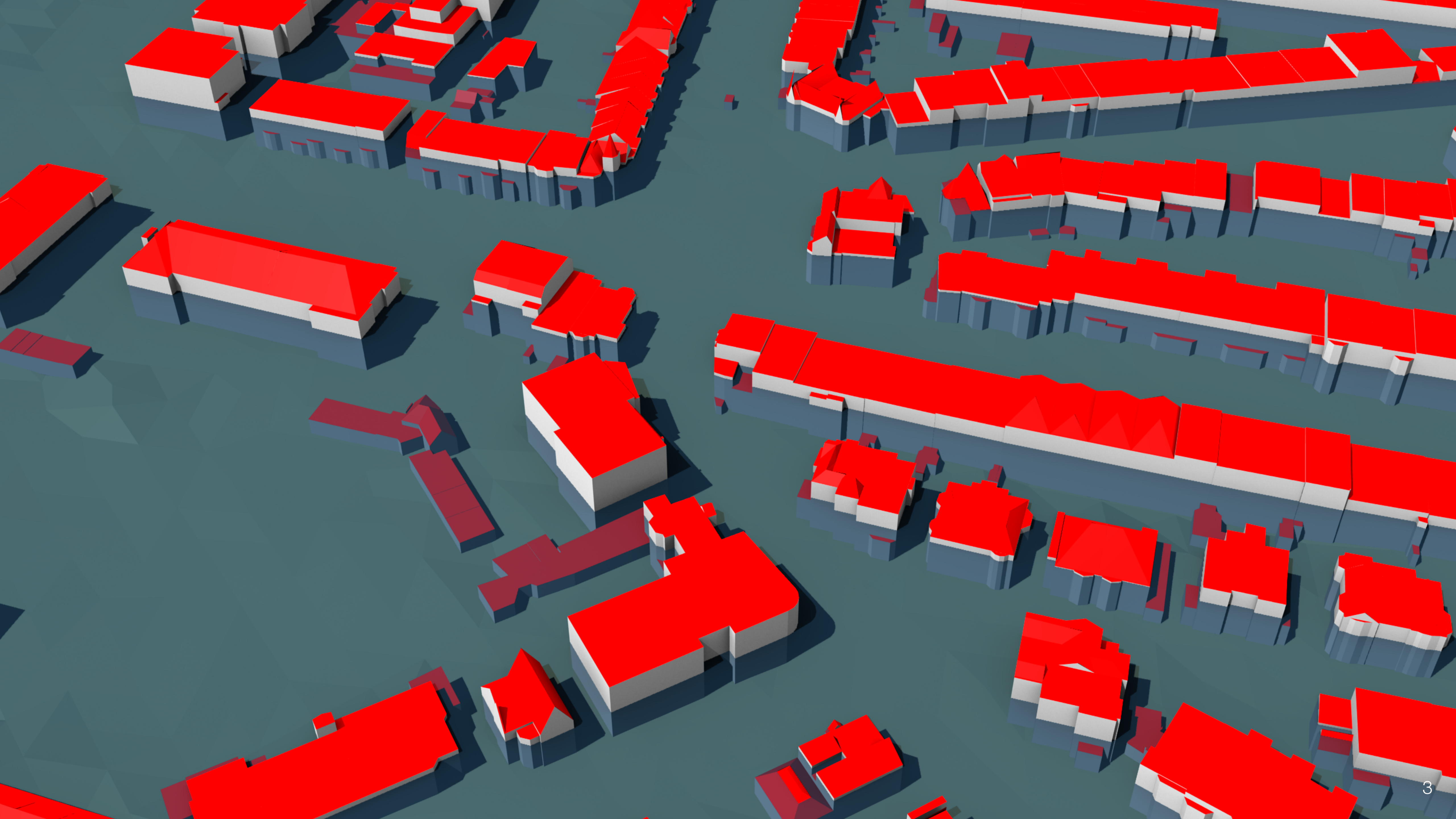
GEO1004:
3D modelling of the built environment

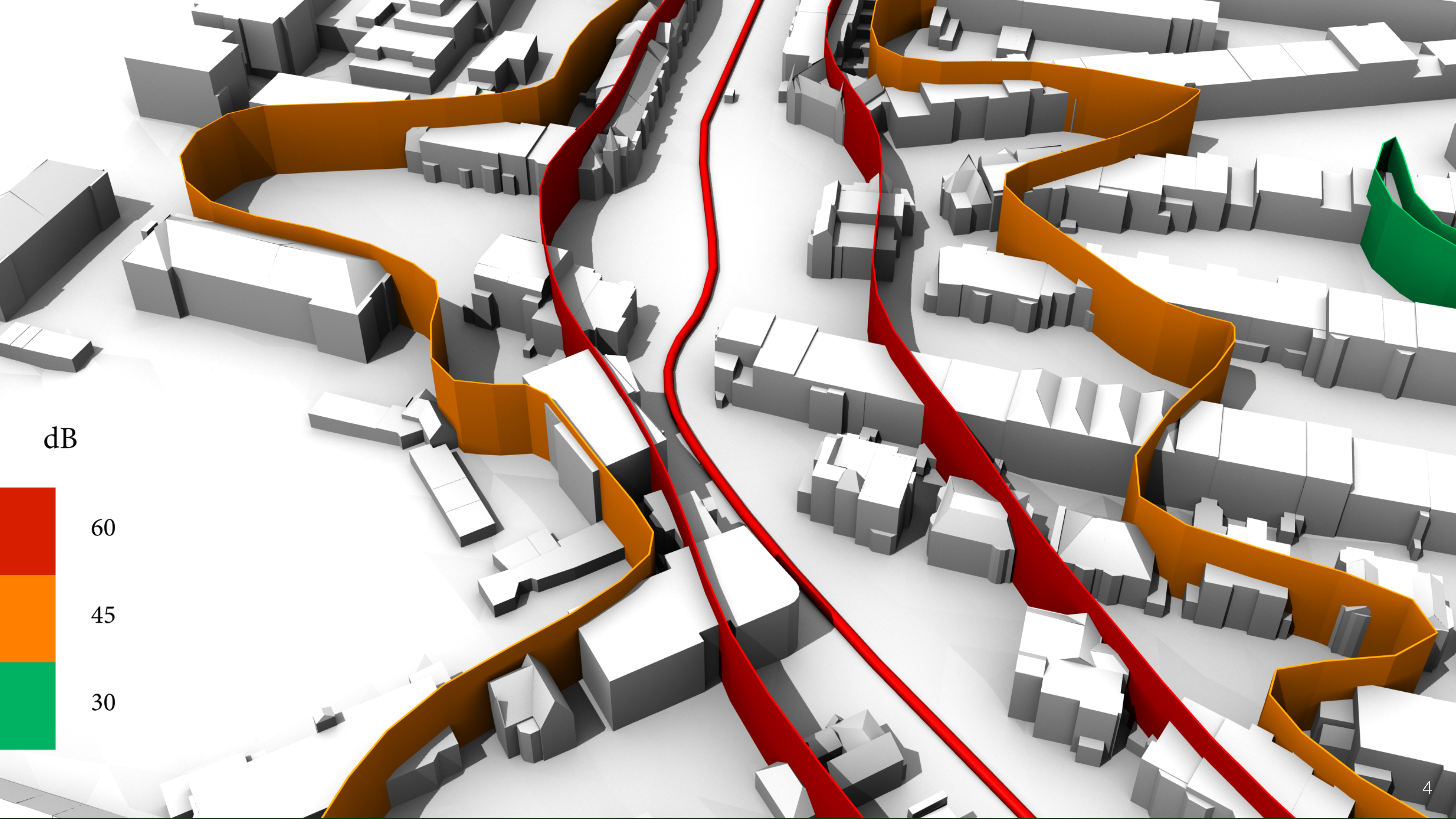


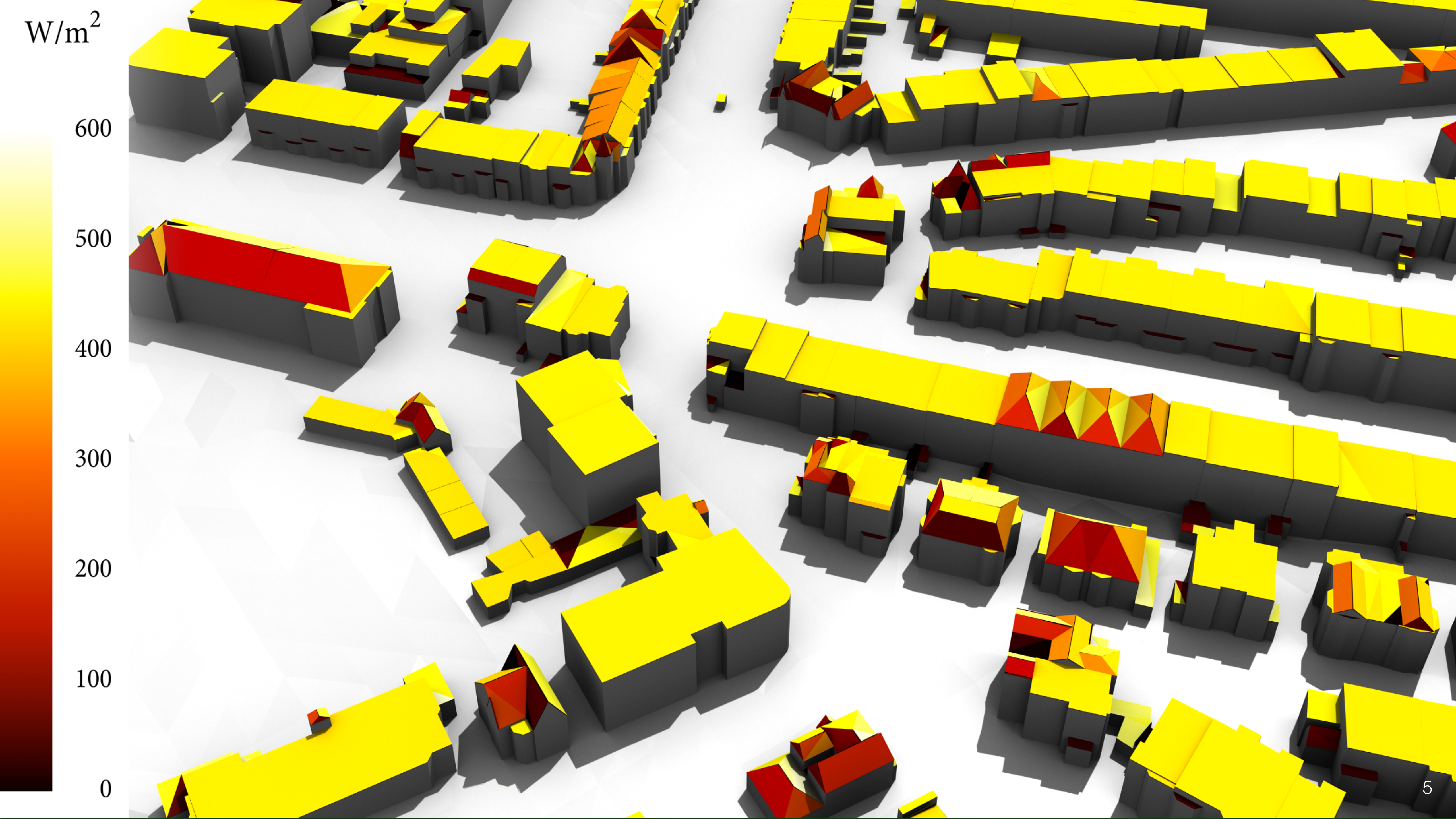
3D geoinformation

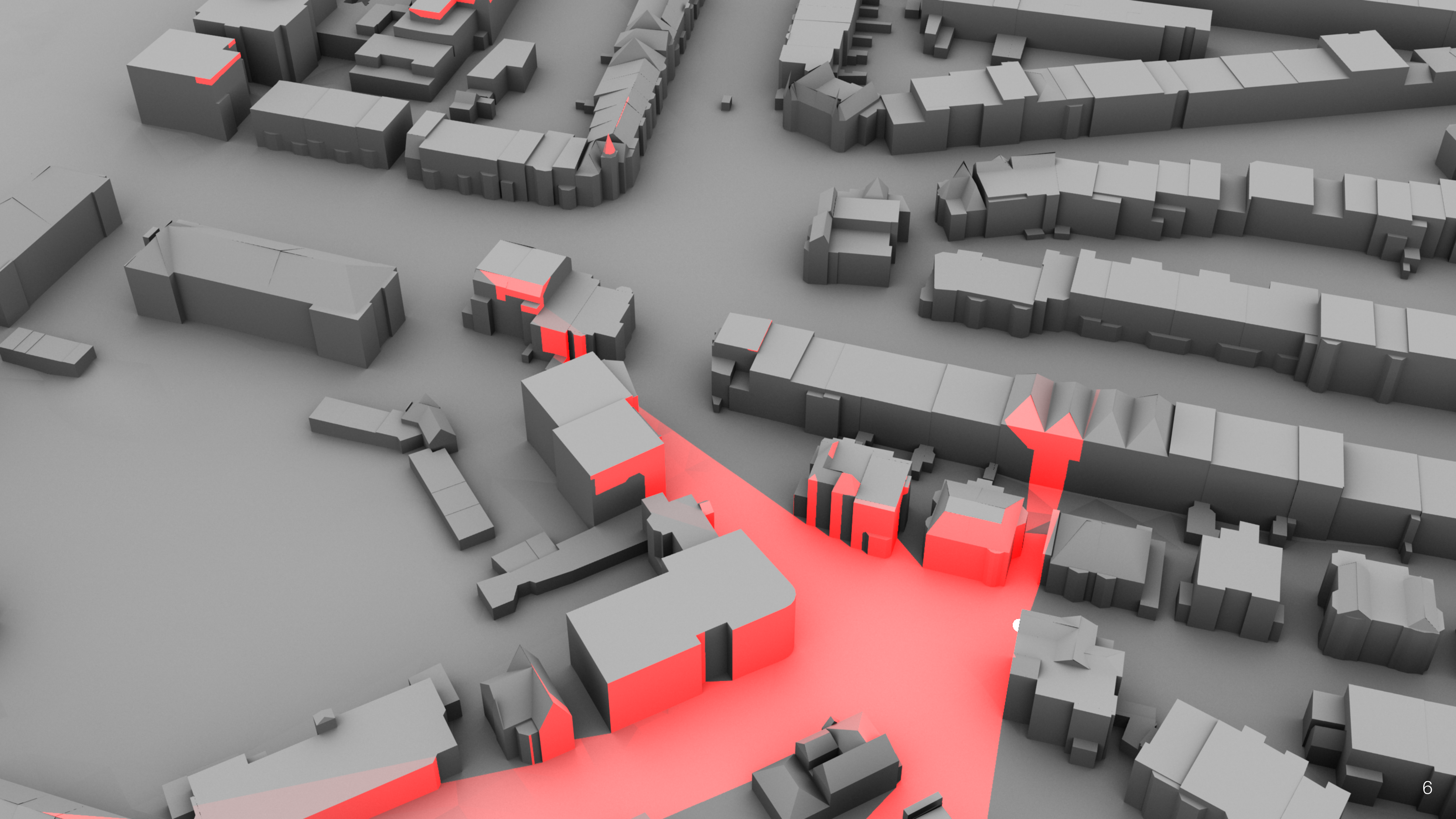
Department of Urbanism
Faculty of Architecture and the Built Environment
Delft University of Technology









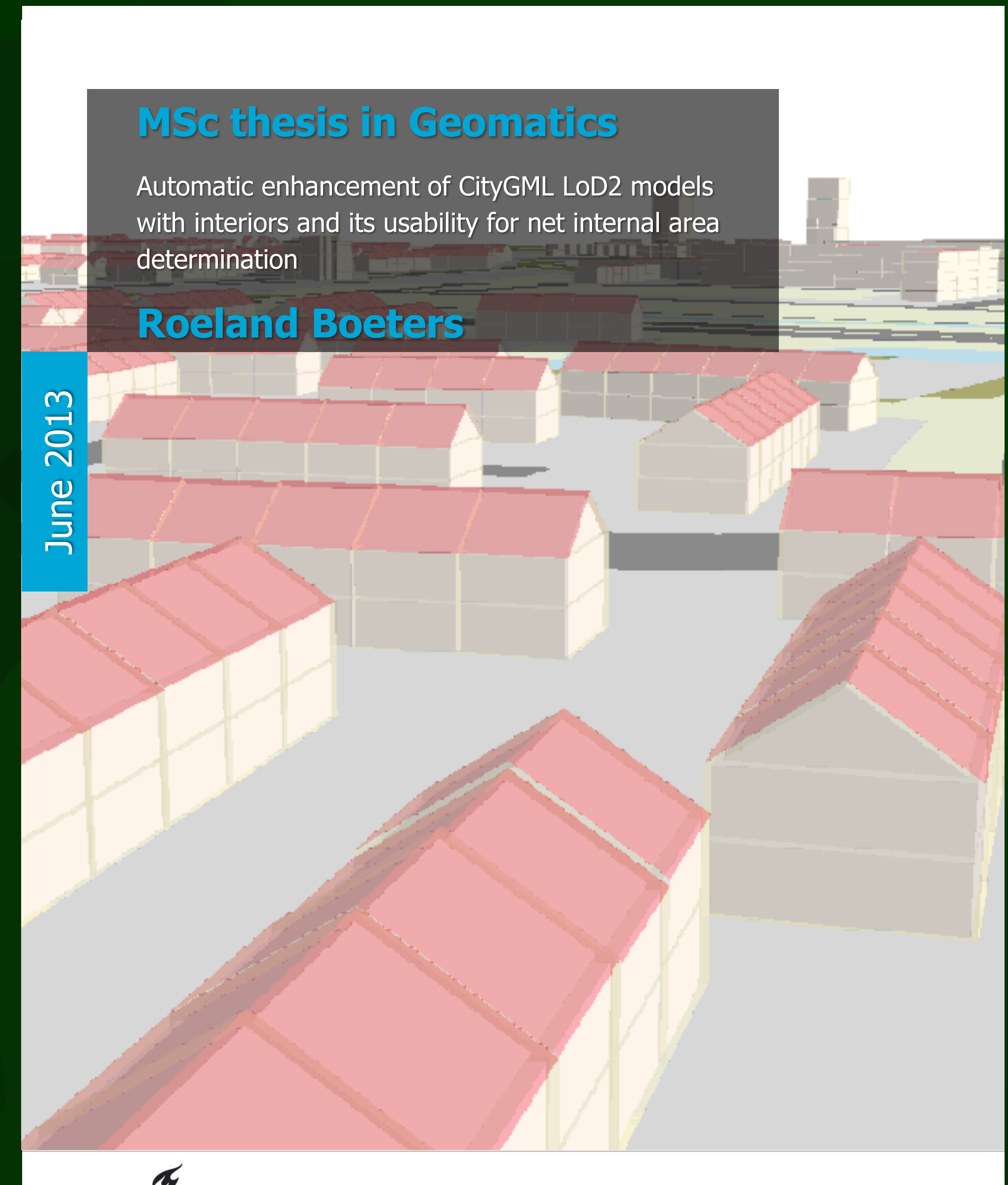


Other applications

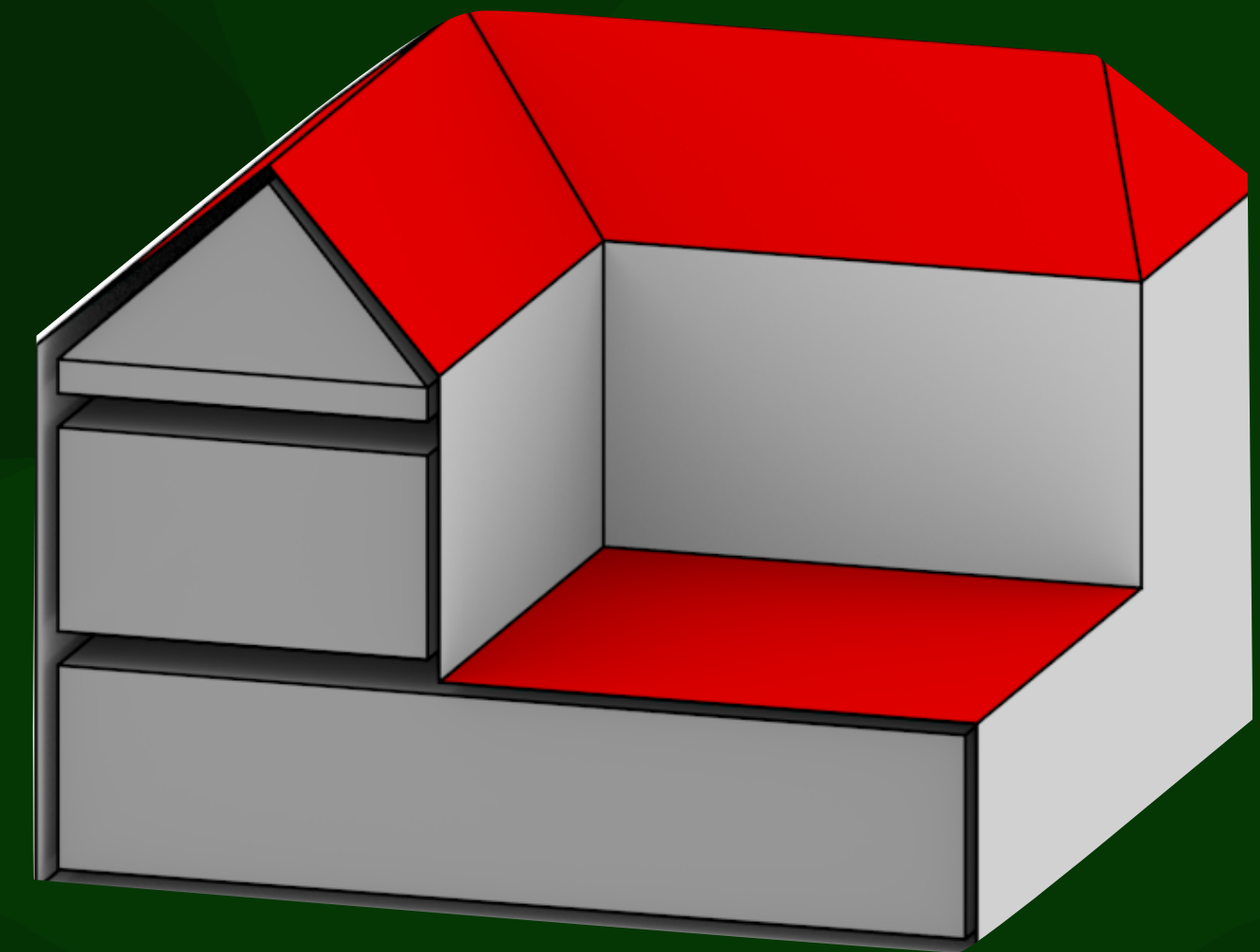
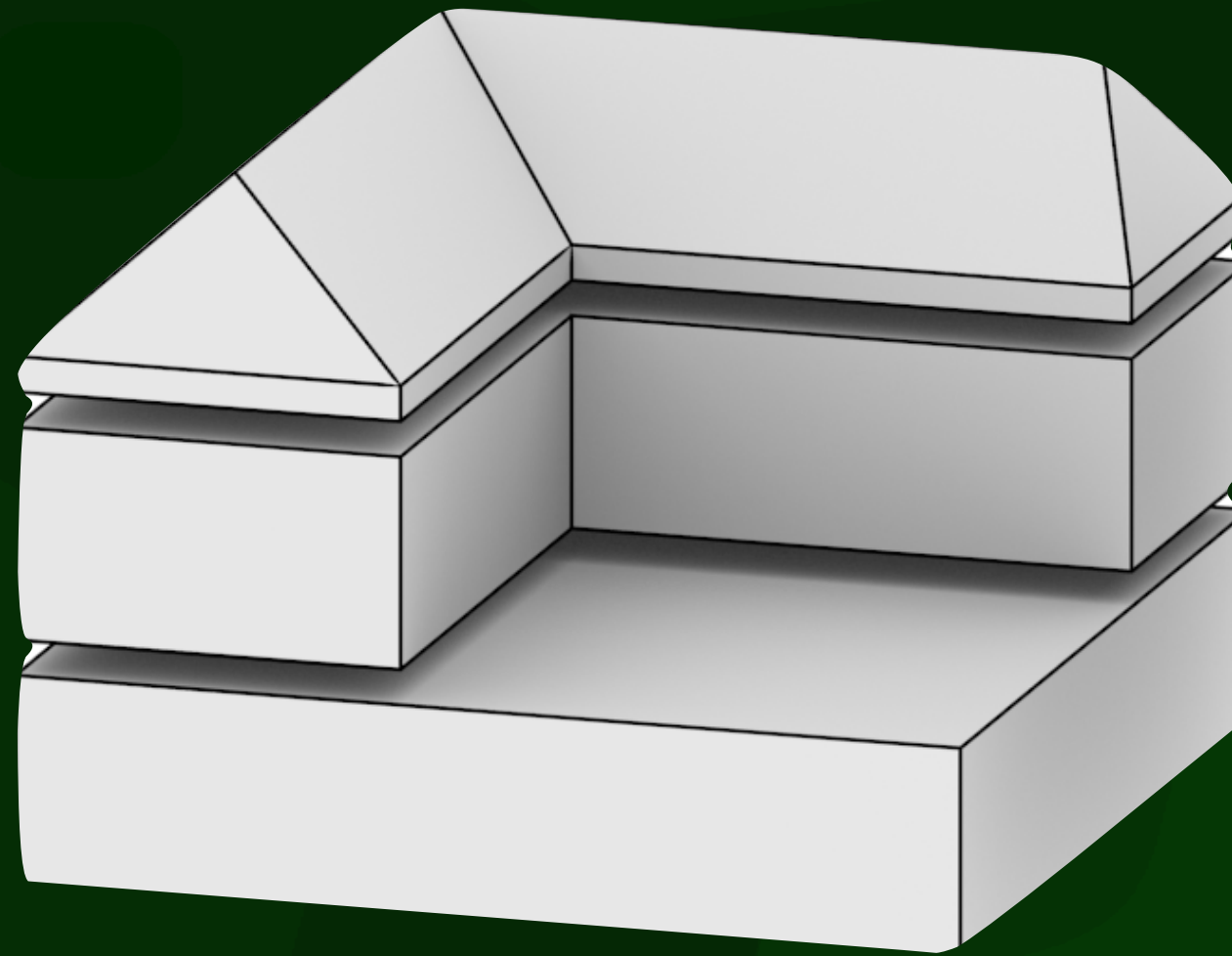
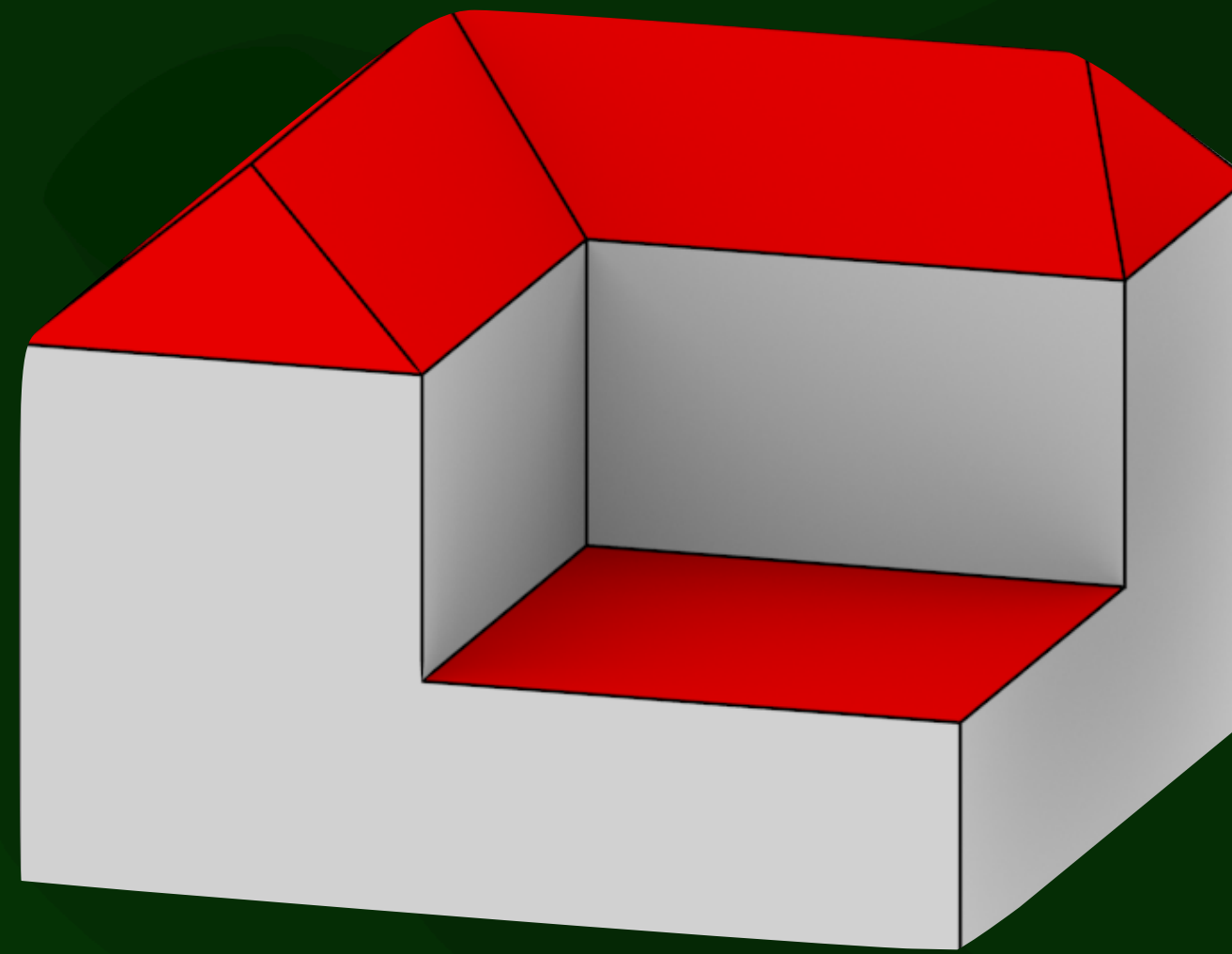
- Visualisation (eg for gaming, tourism, navigation, etc)
- Energy demand estimation (and potential for retrofitting)
- Computational fluid dynamics (eg for wind speeds, air quality, effects on buildings, etc)
- Shadow casting (eg for building permits, visibility analysis, improving energy demand/solar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

Some 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+



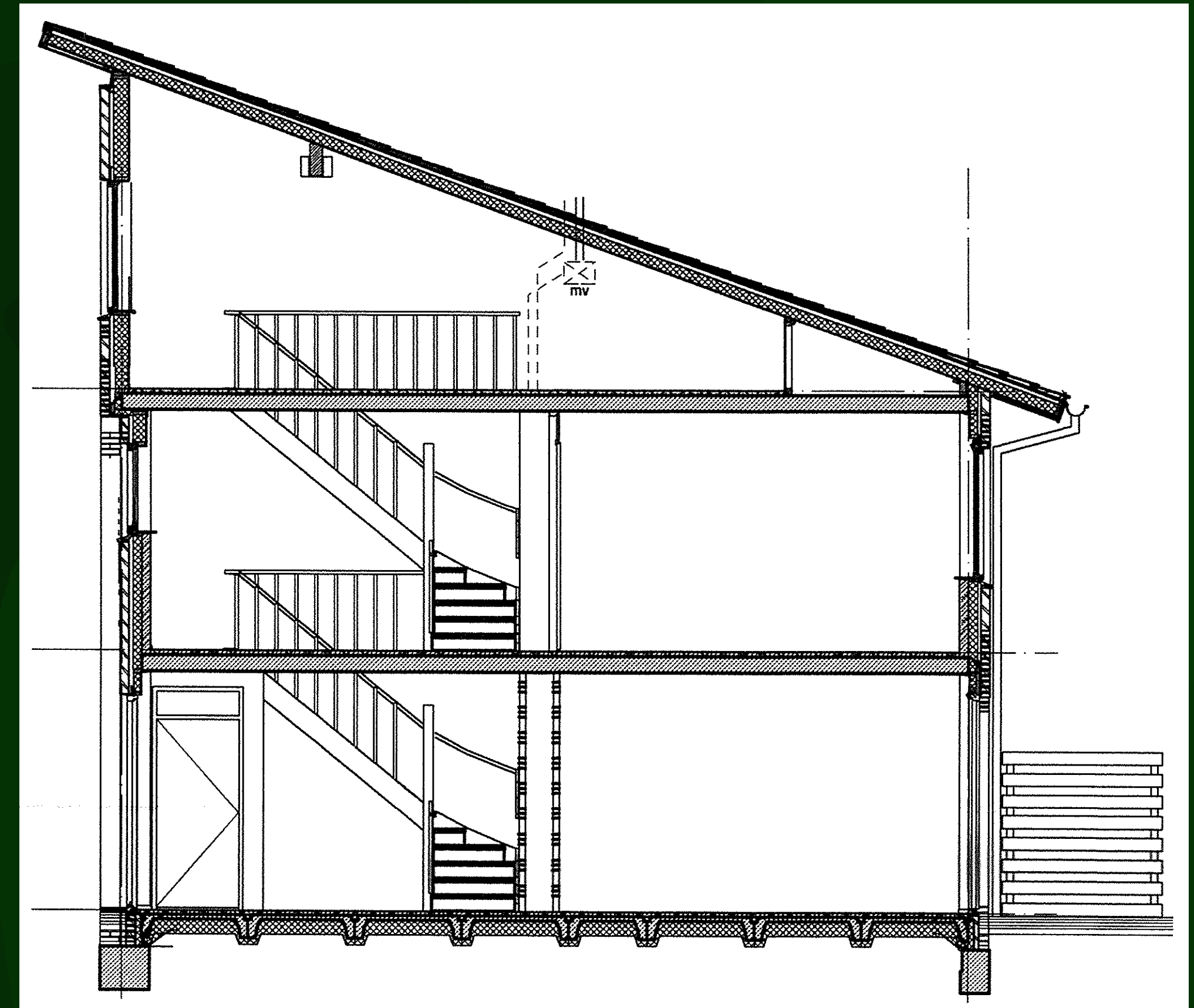
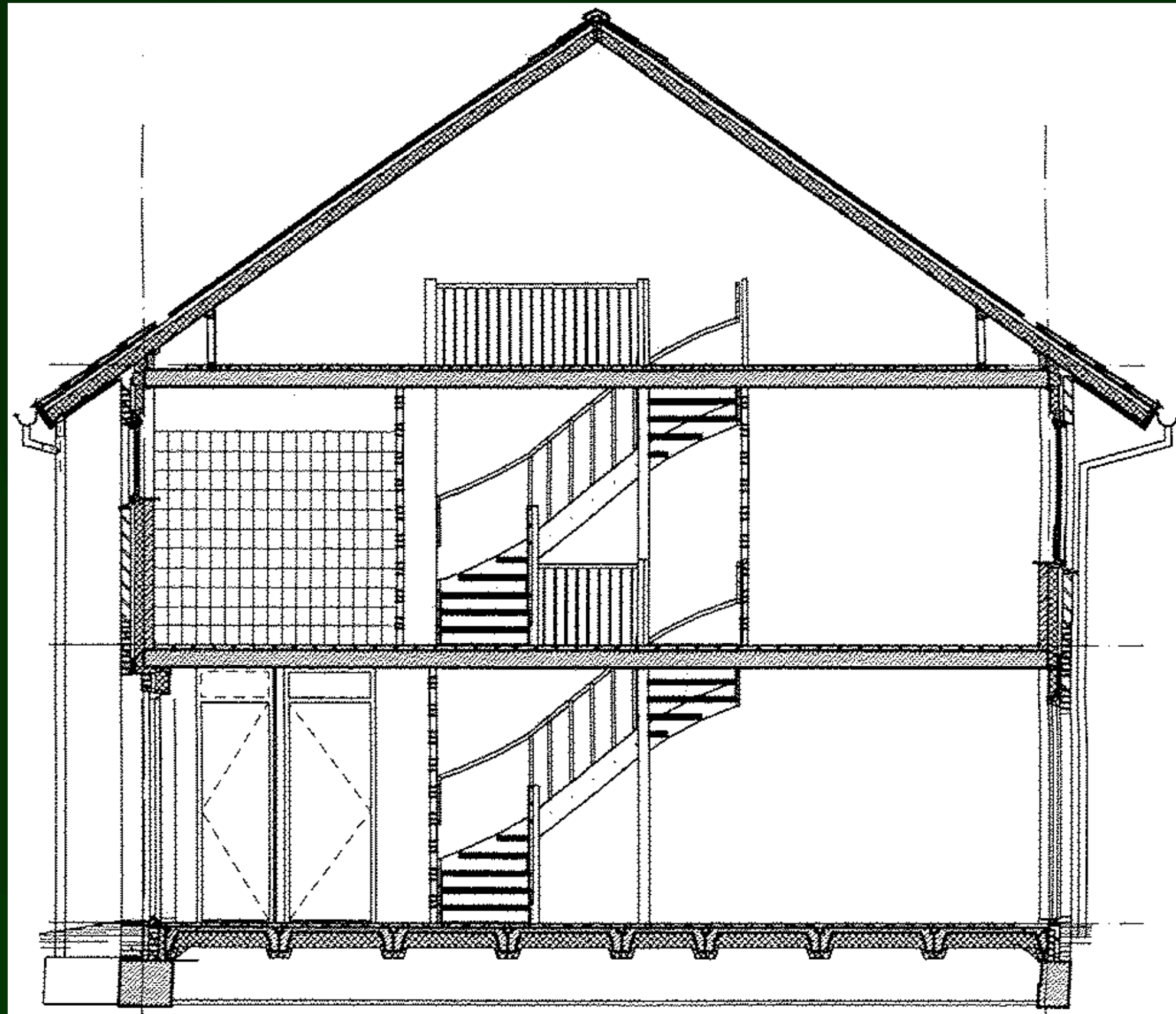
Exterior in LOD2

Buildings bodies are prisms
Simple roof shapes
Thematically classified boundary surfaces
No openings in the exterior geometry

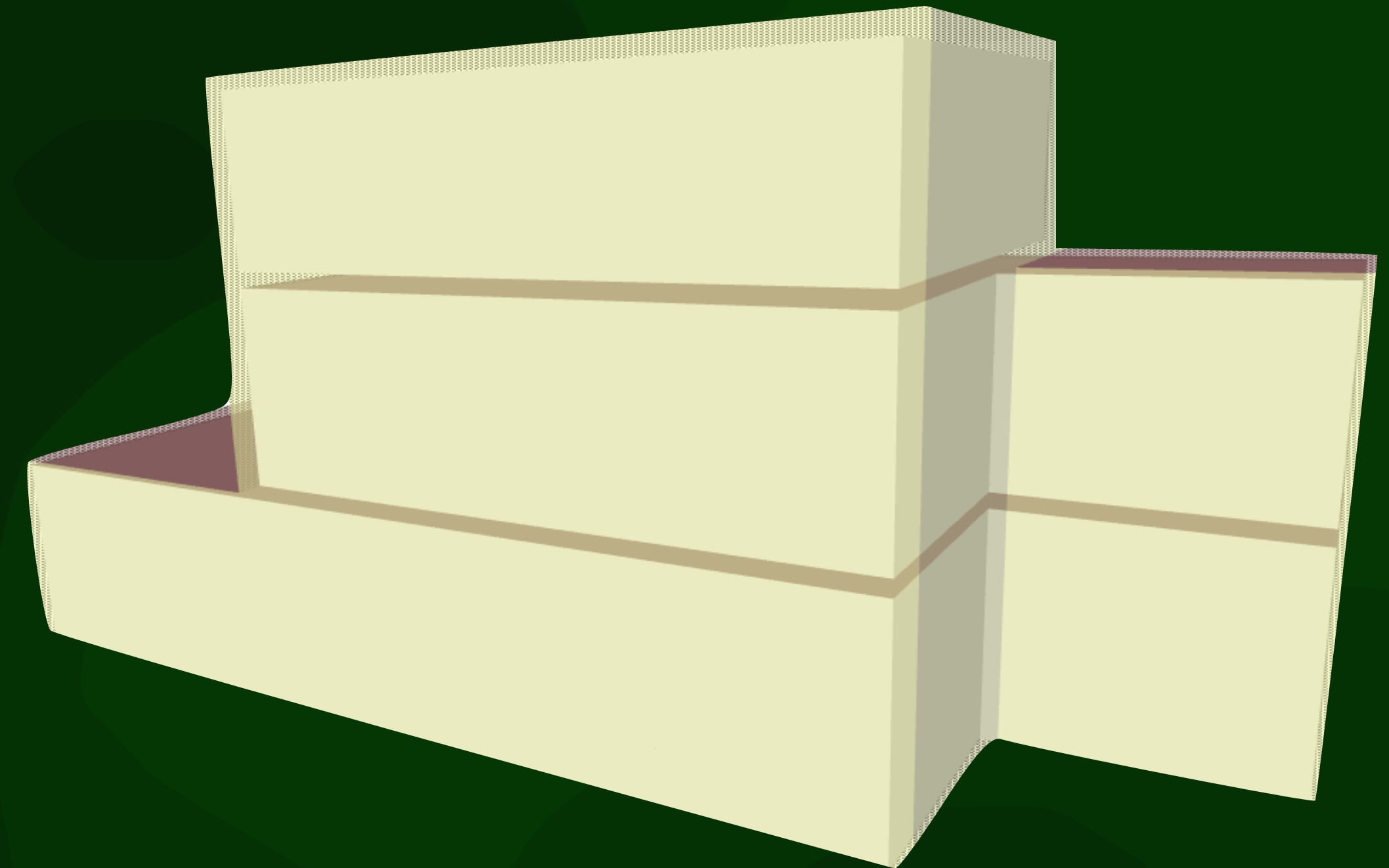
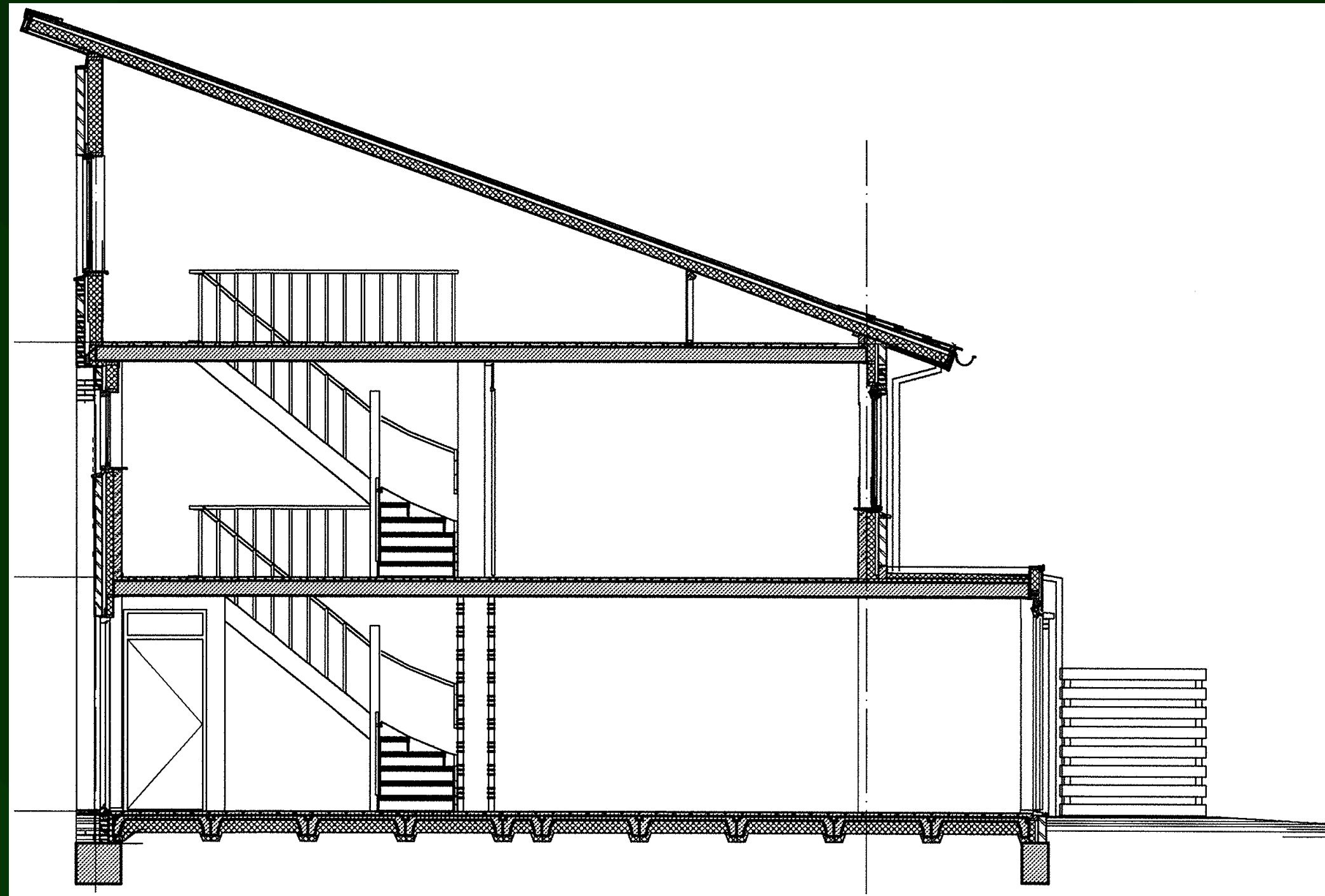
Interior in LOD2+

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



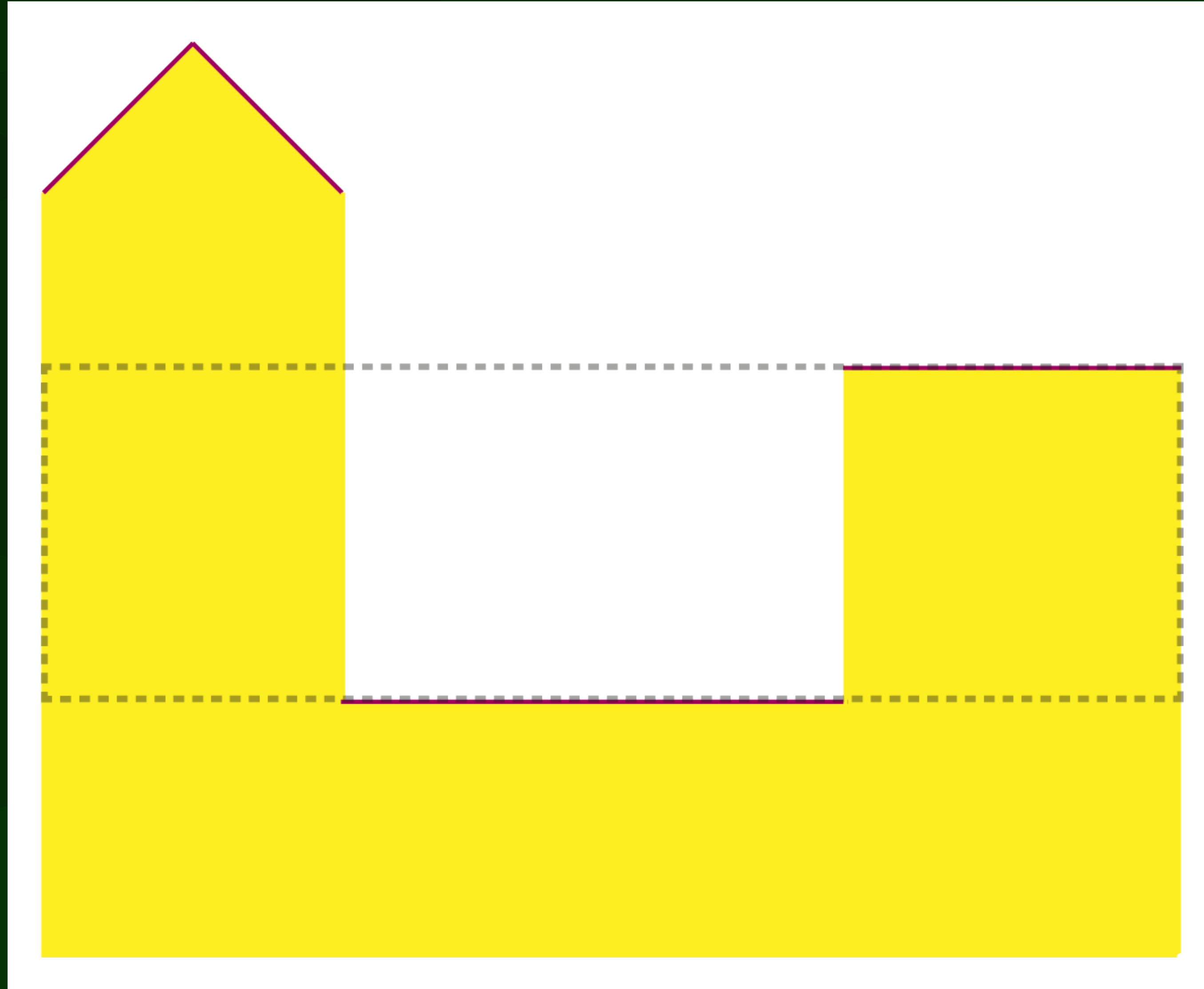
Indication of storeys



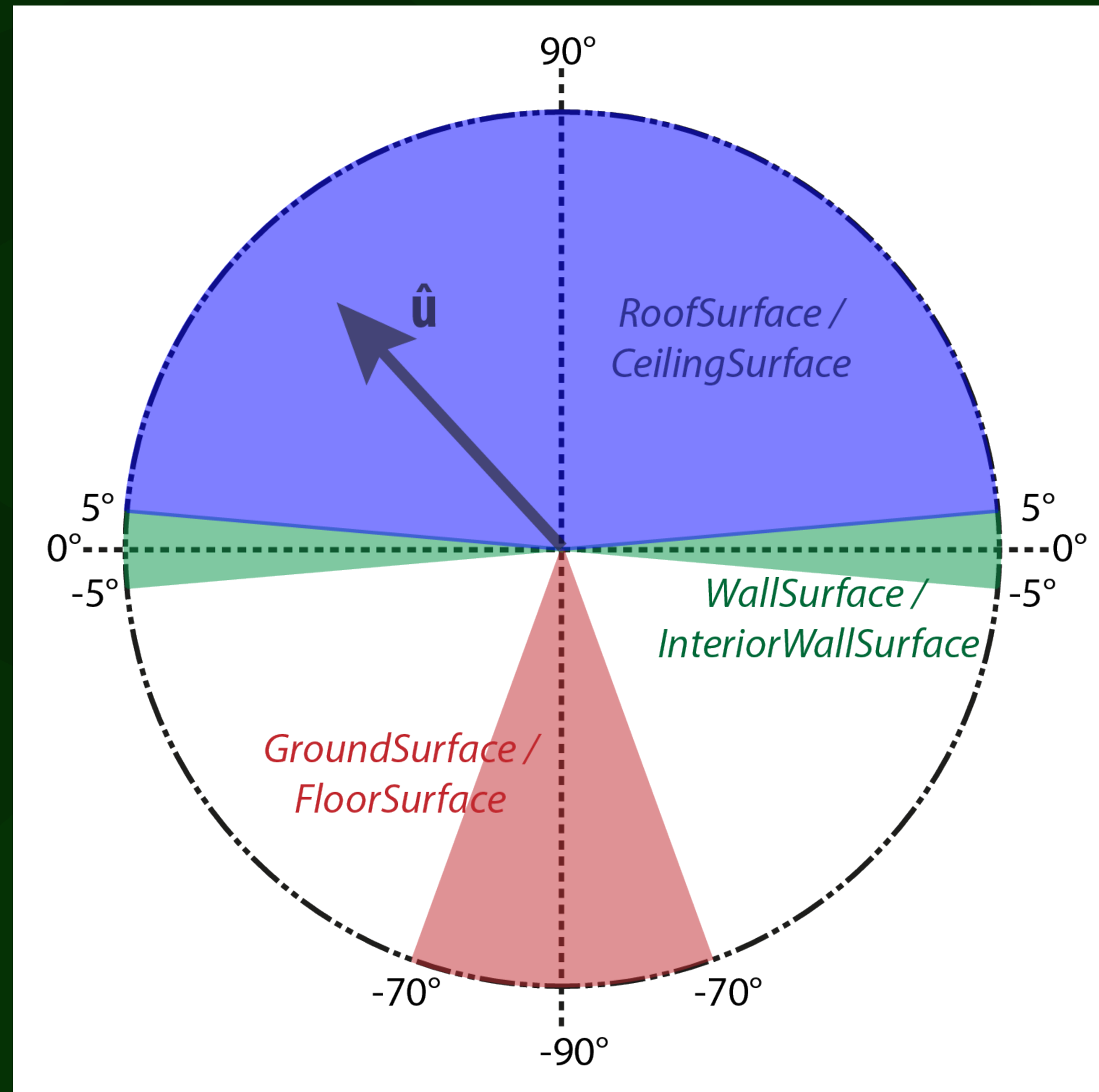
Wall thickness

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

Boolean set intersection



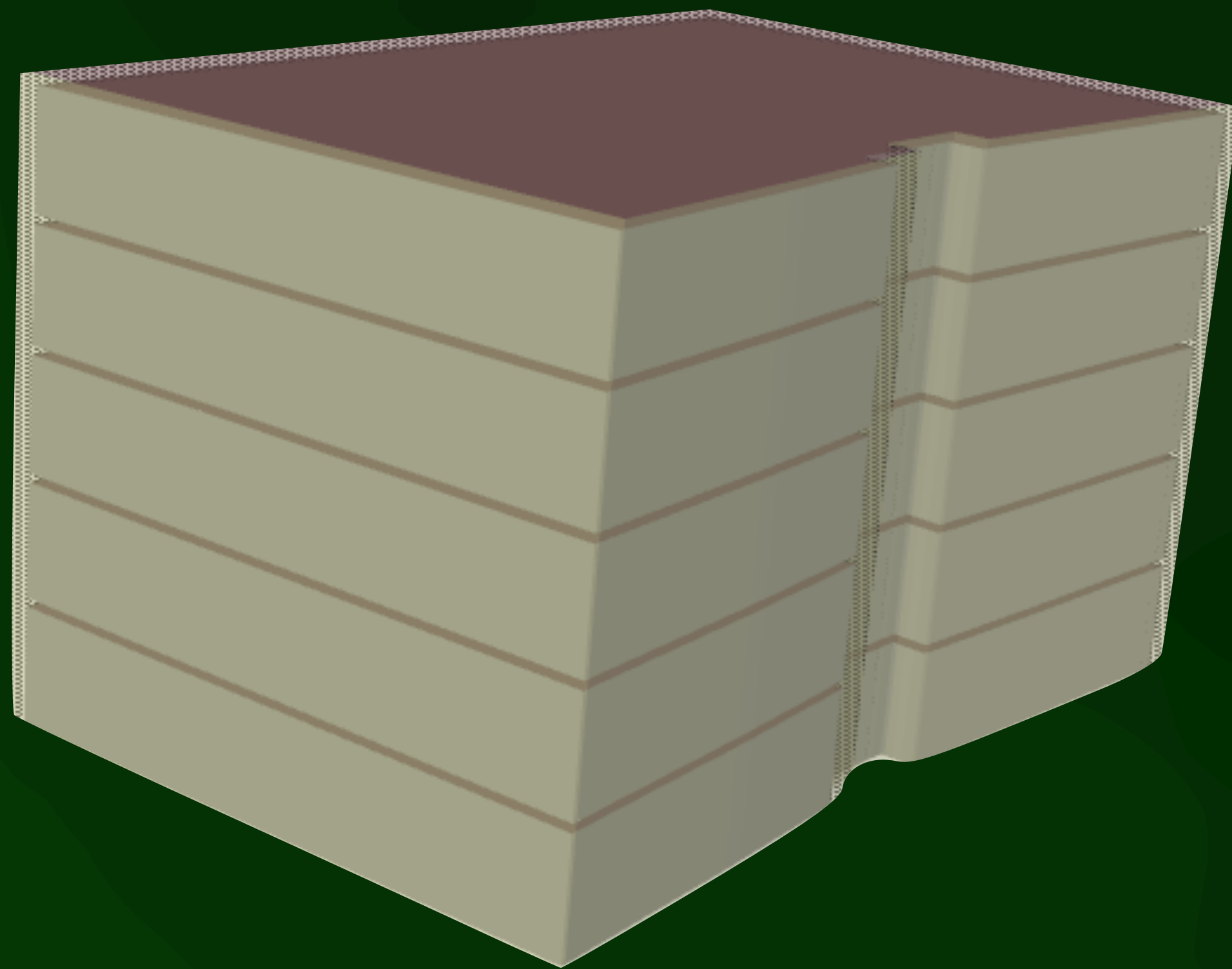
Classifying surfaces



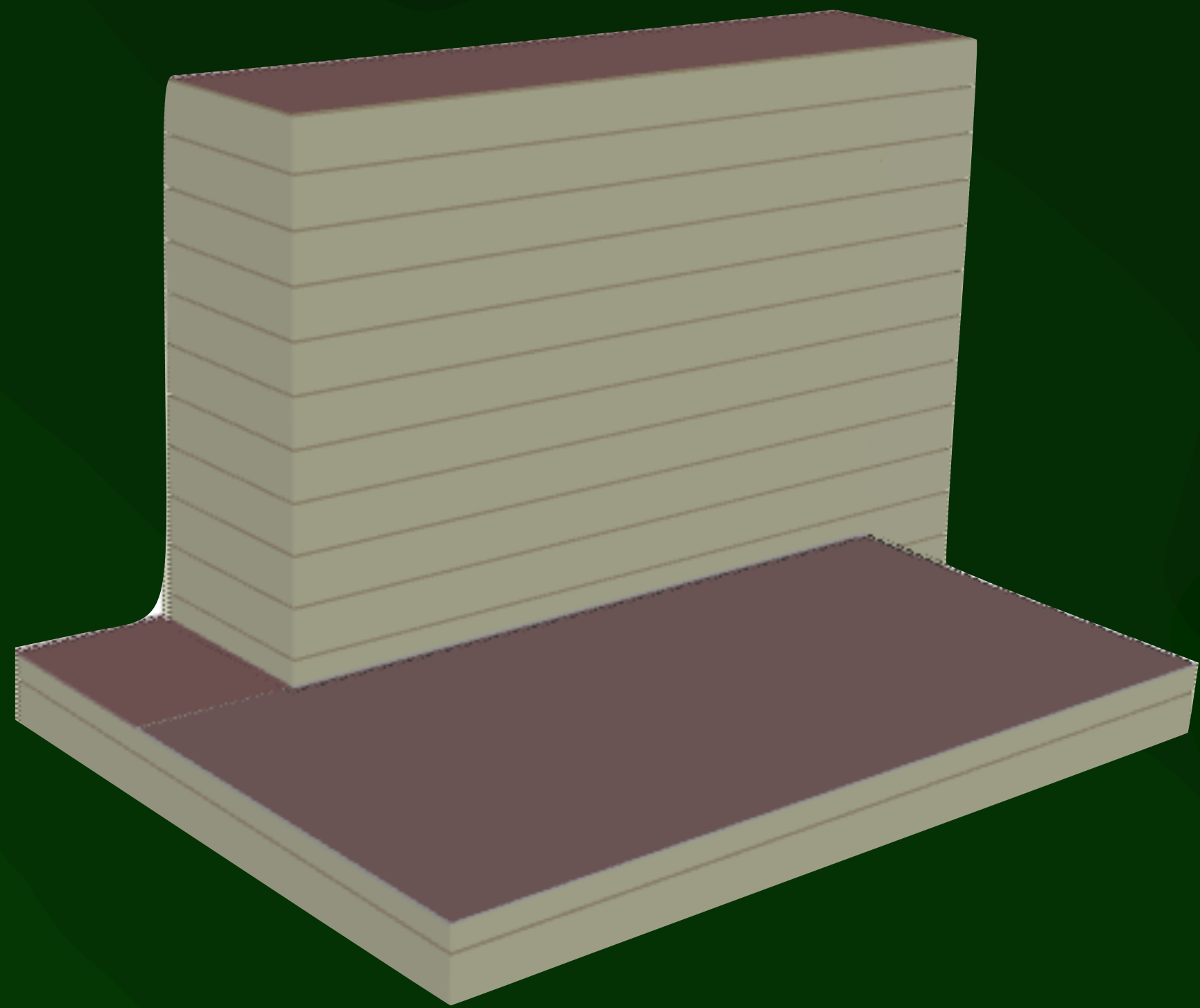
Results



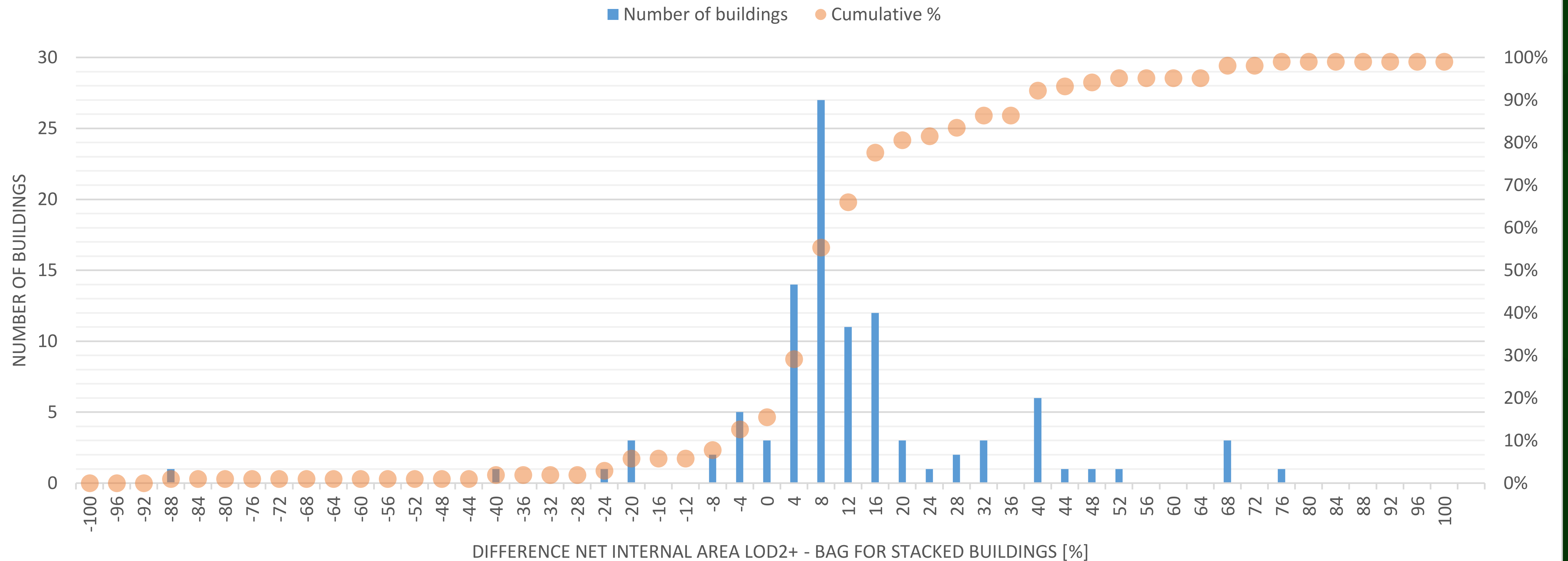
Results



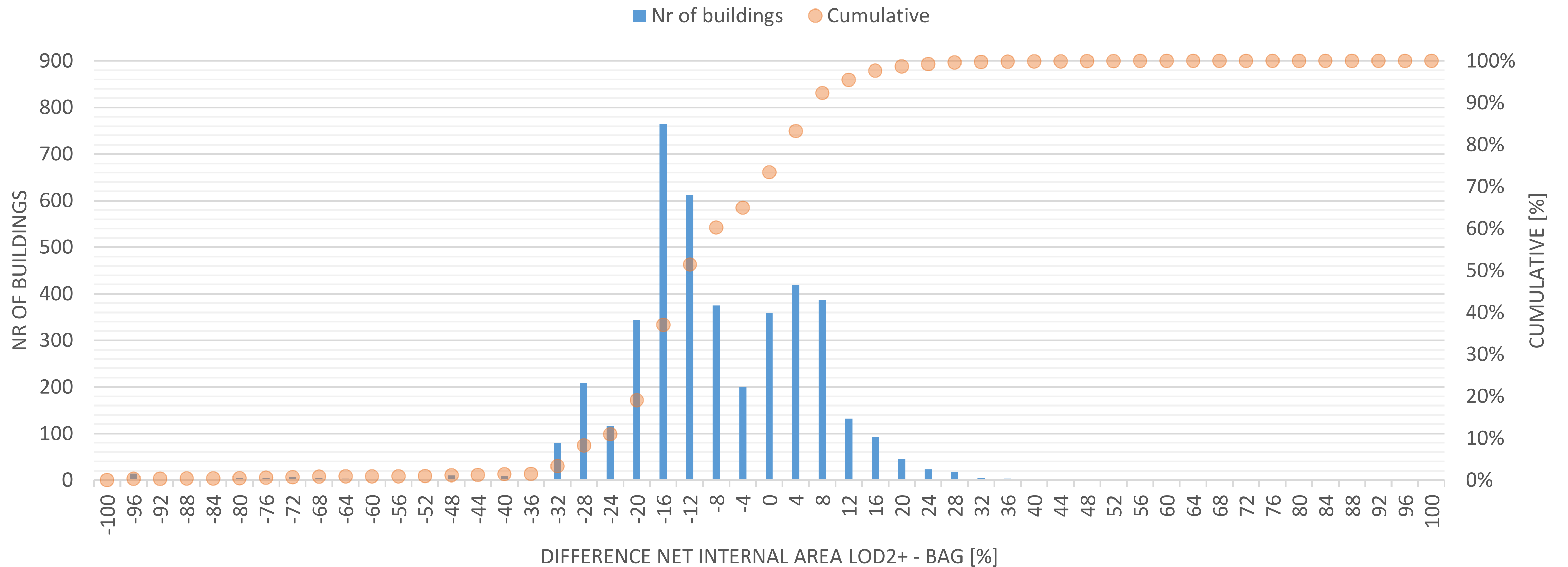
Results



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

Automatic generation of CityGML LoD3 building models from IFC models

MSc thesis in Geomatics
by Sjors Donkers

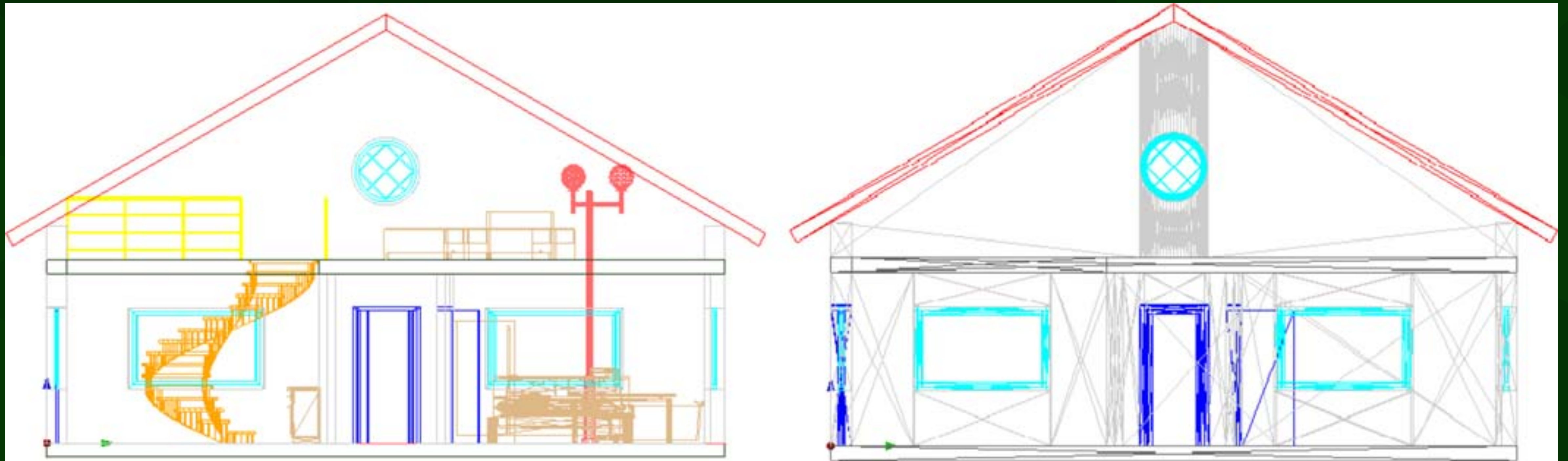


December 2013

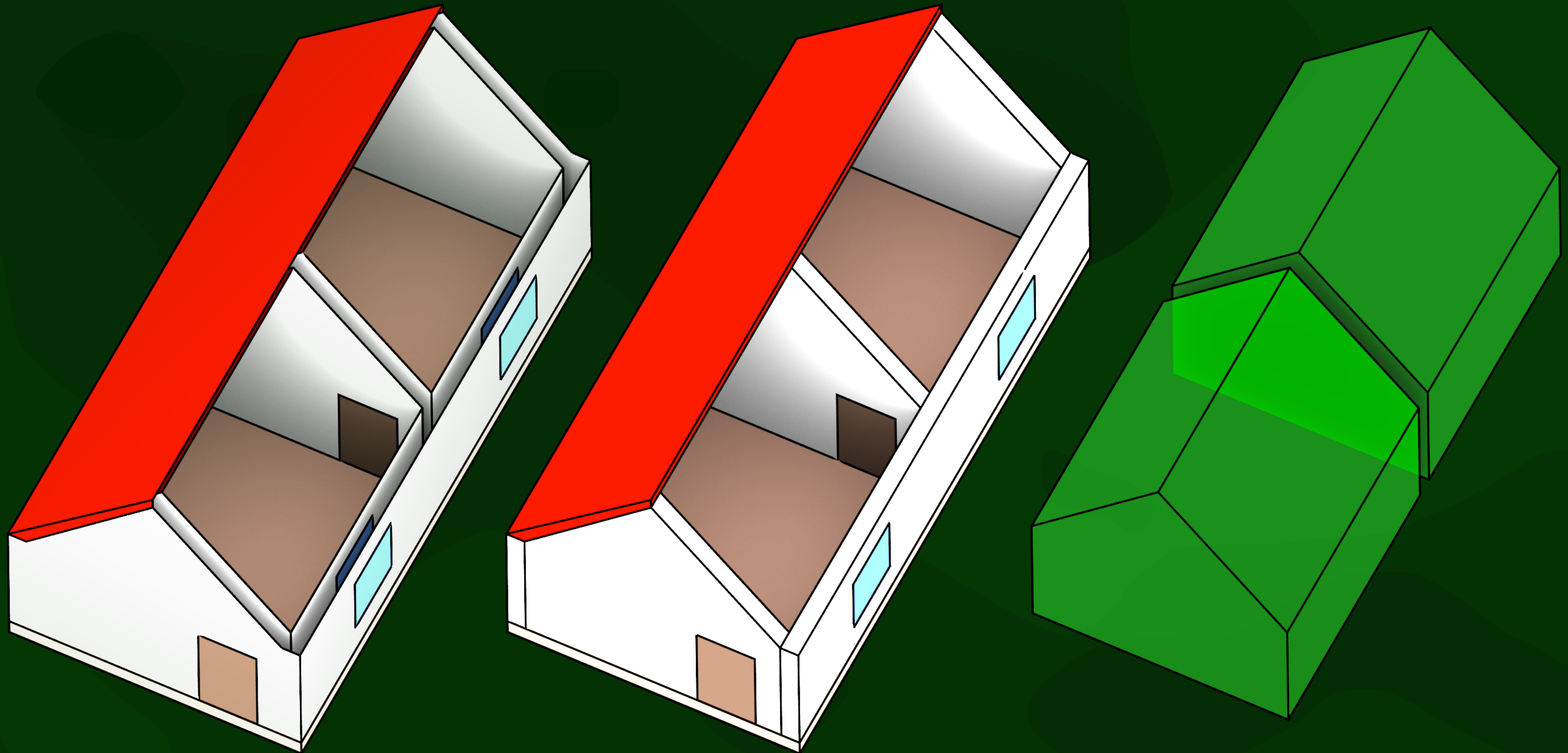


Department of GIS Technology
OTB Research Institute for the Built Environment

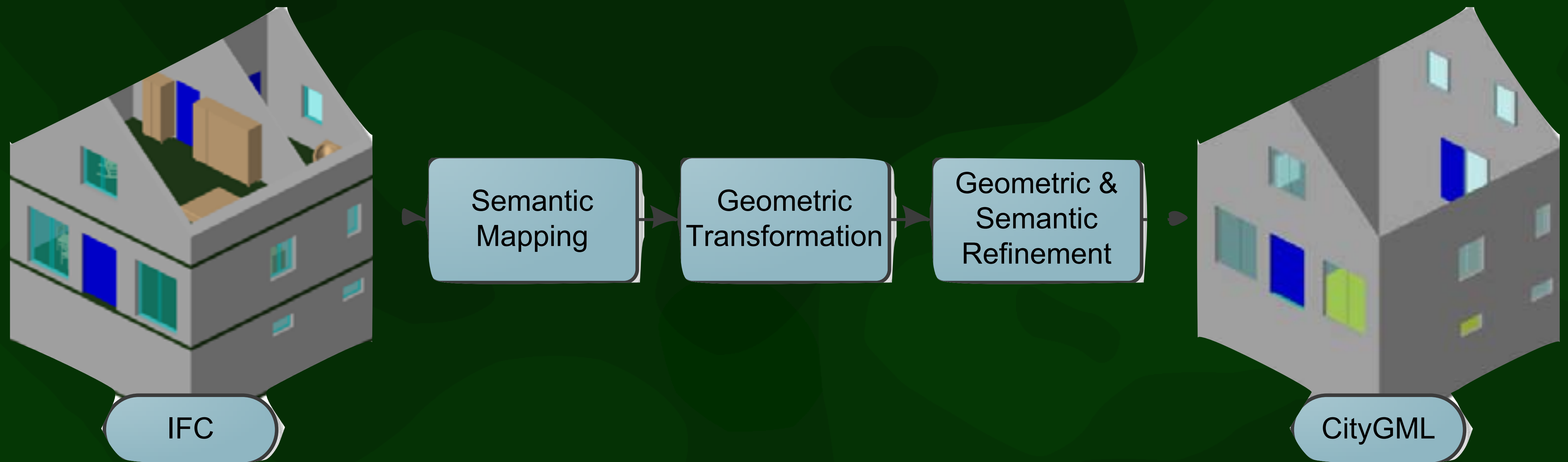
Goal



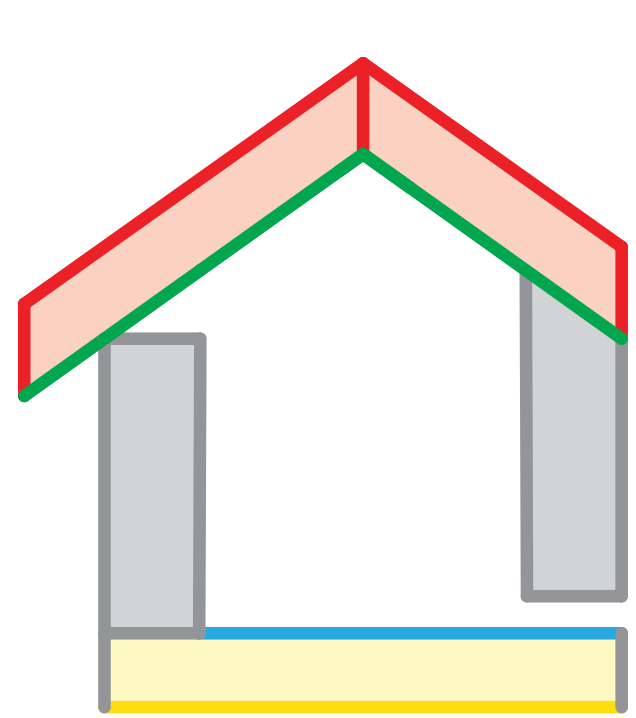
3DCM vs BIM



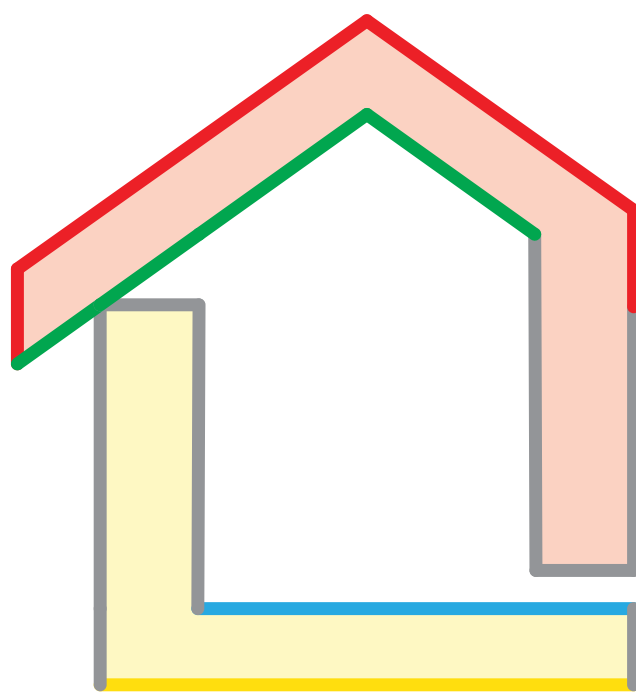
Methodology (semantics)



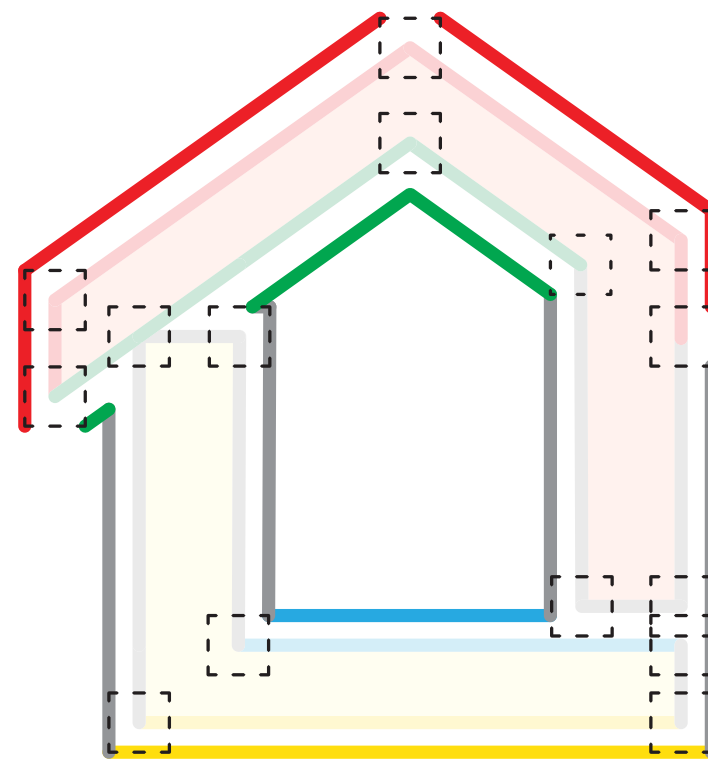
Methodology (geometry)



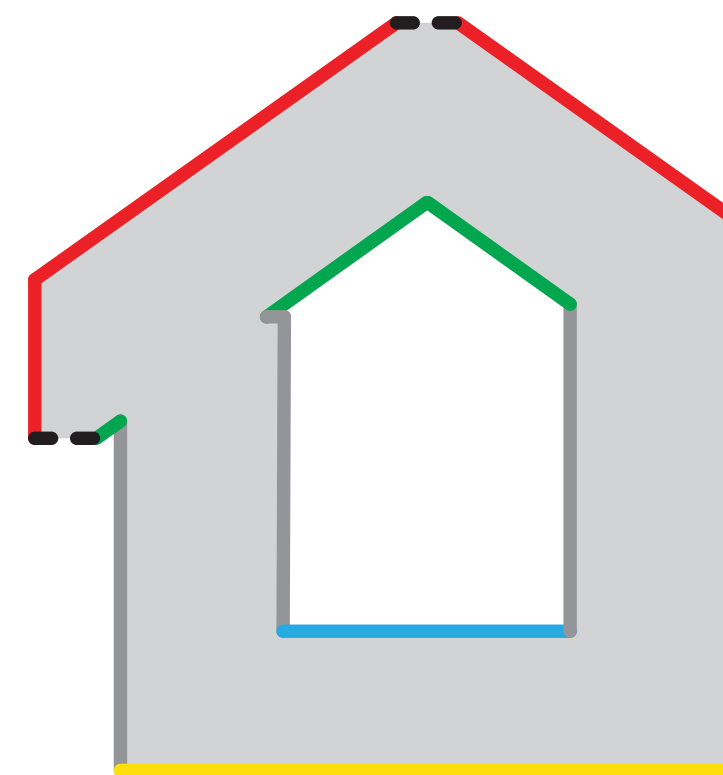
(a) input



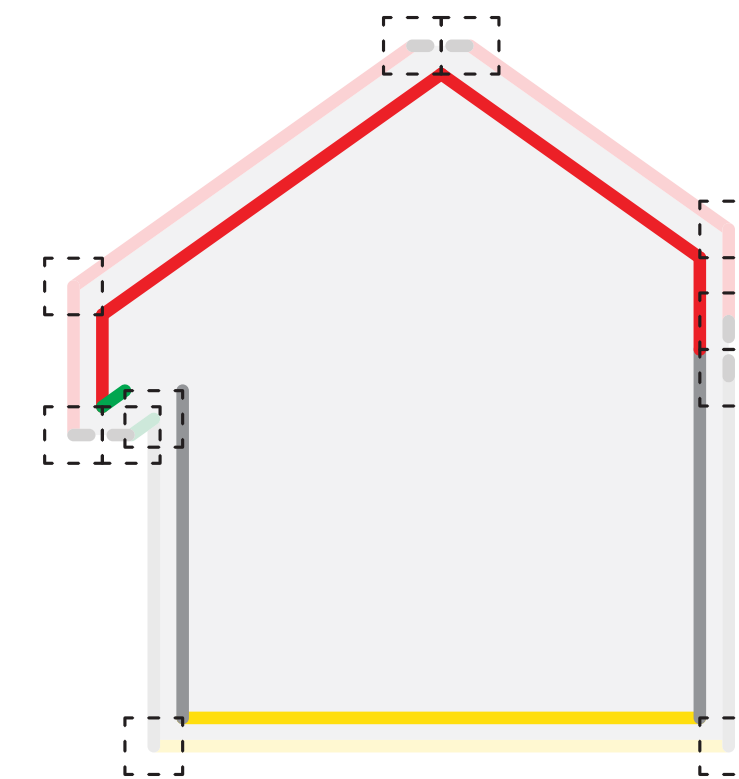
(b) union



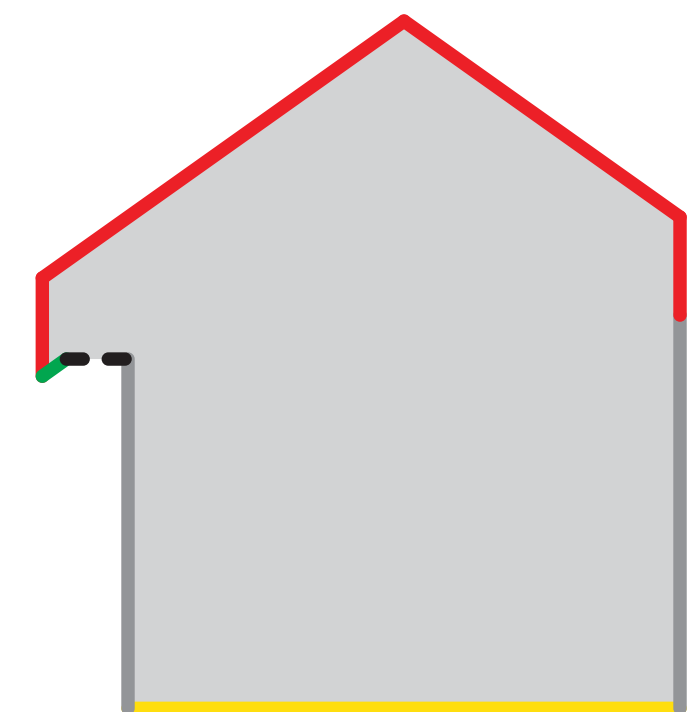
(c) dilation



(d) result



(e) erosion

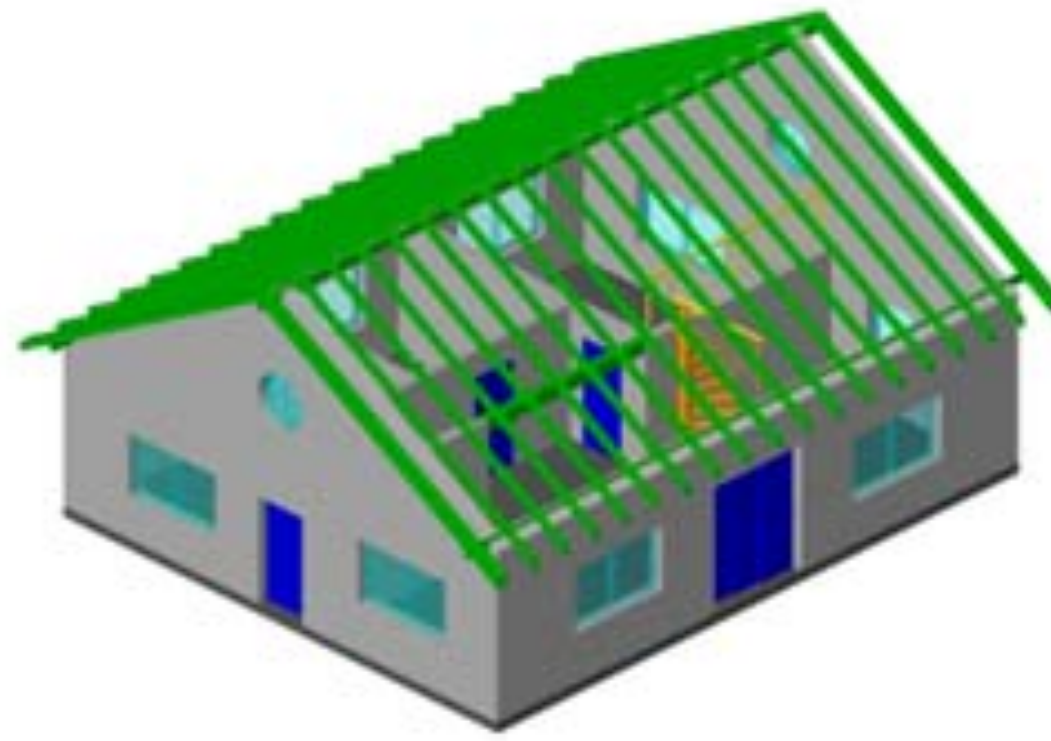


(f) final result

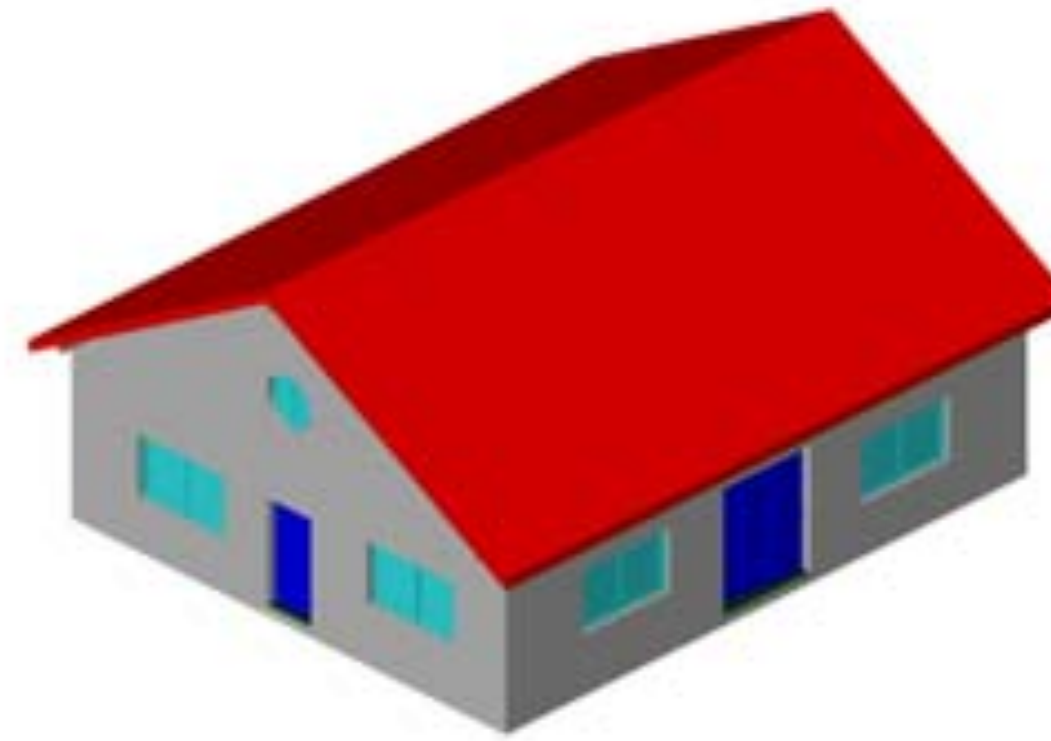
Results



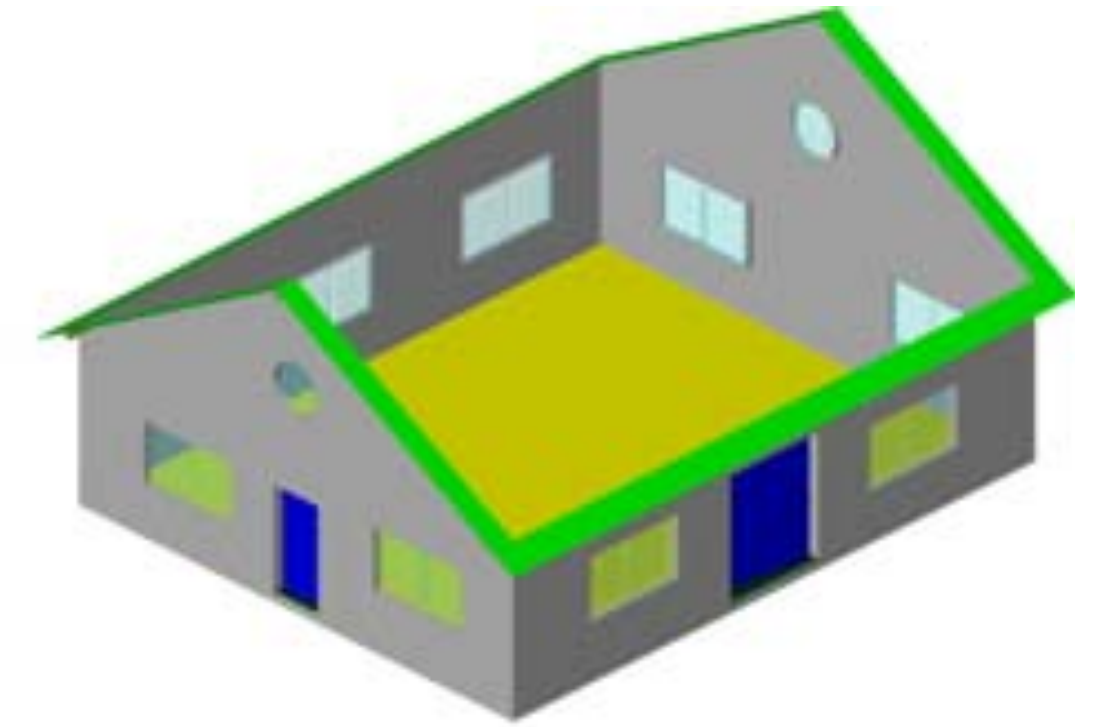
(a) input IFC



(b) IFC without roof

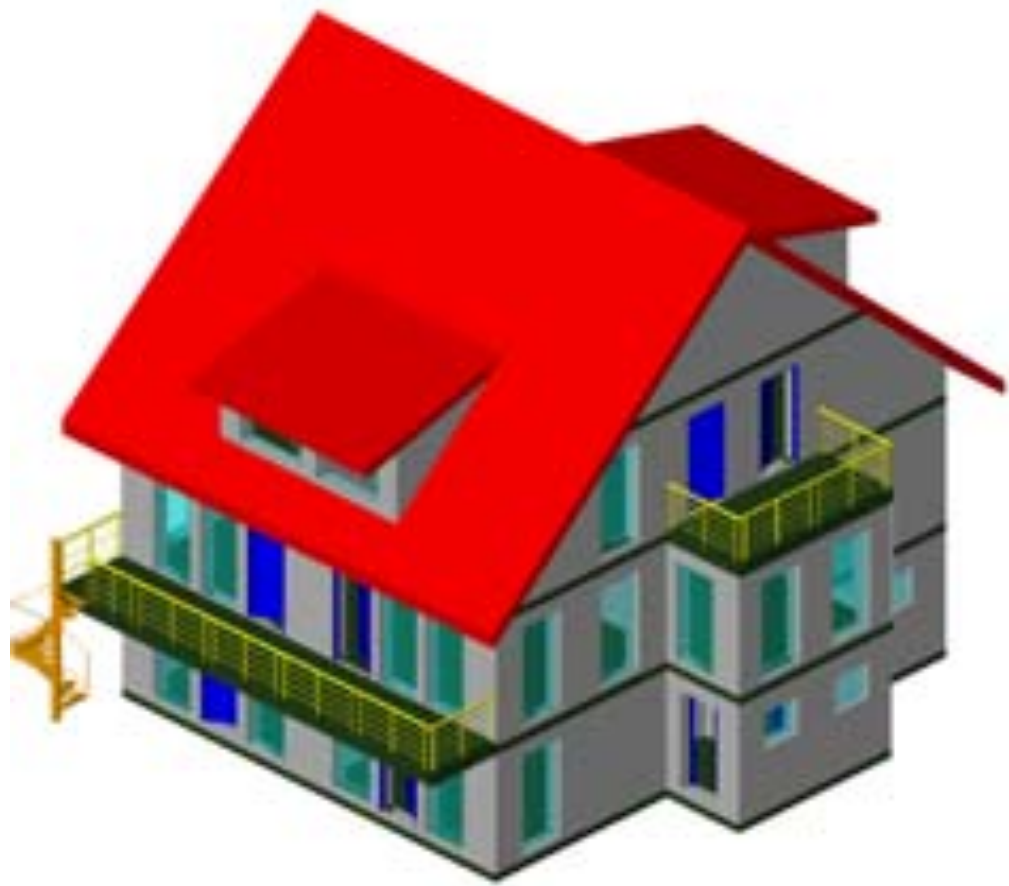


(c) output CityGML

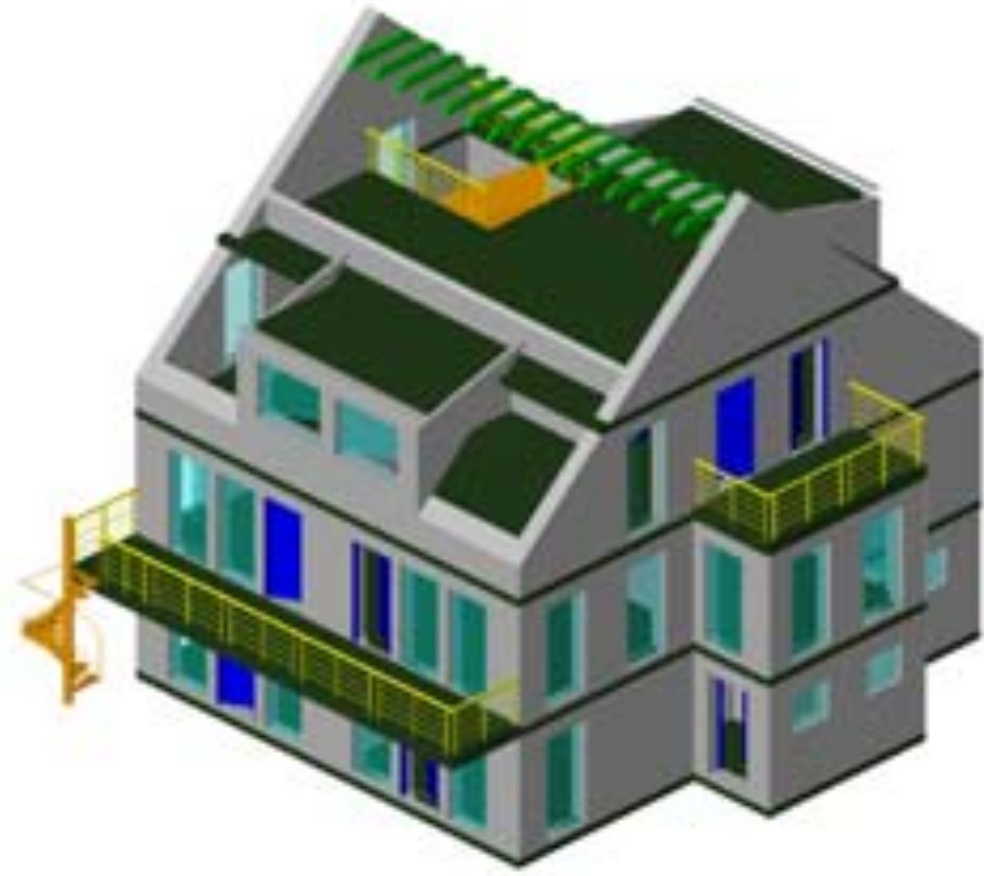


(d) CityGML without roof

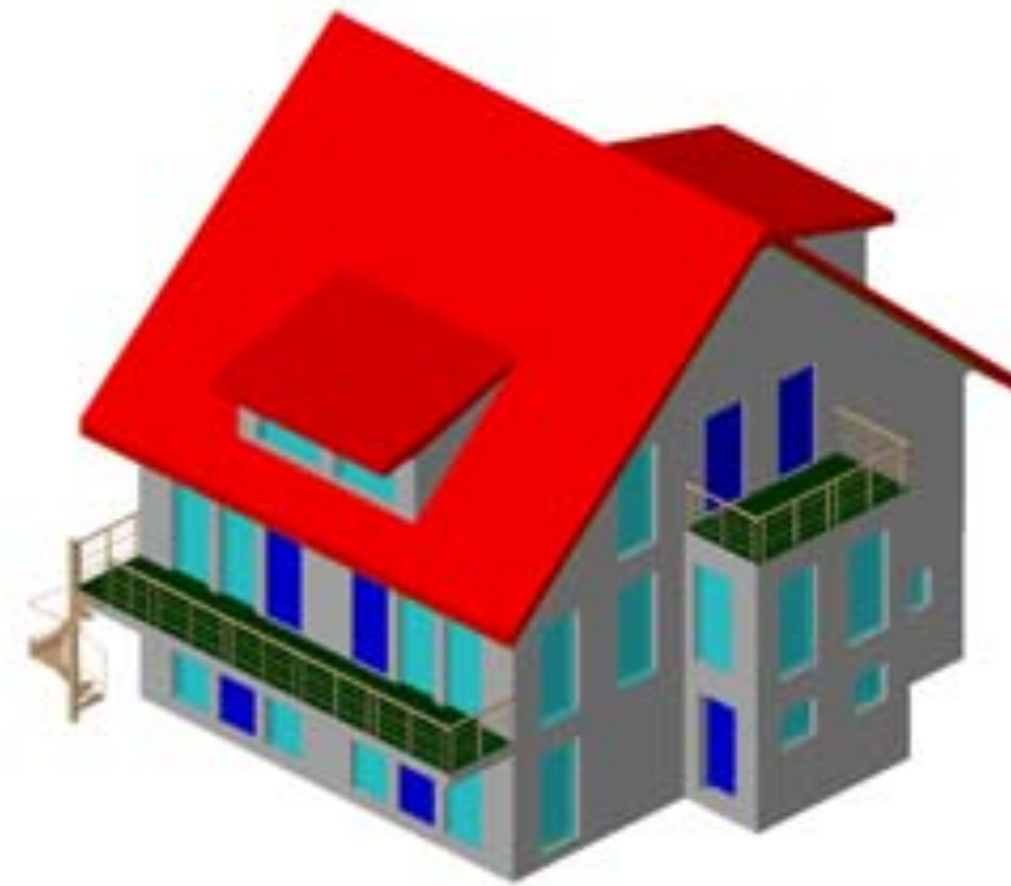
Results



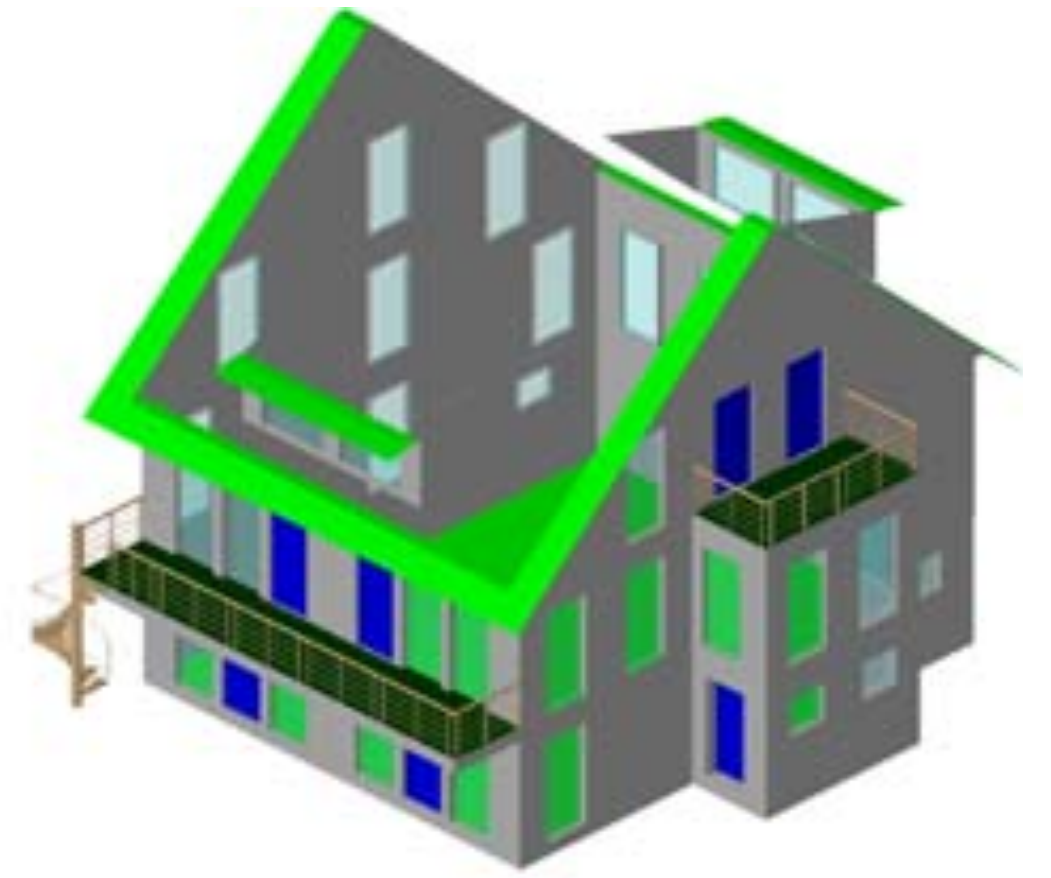
(a) input IFC



(b) IFC without roof

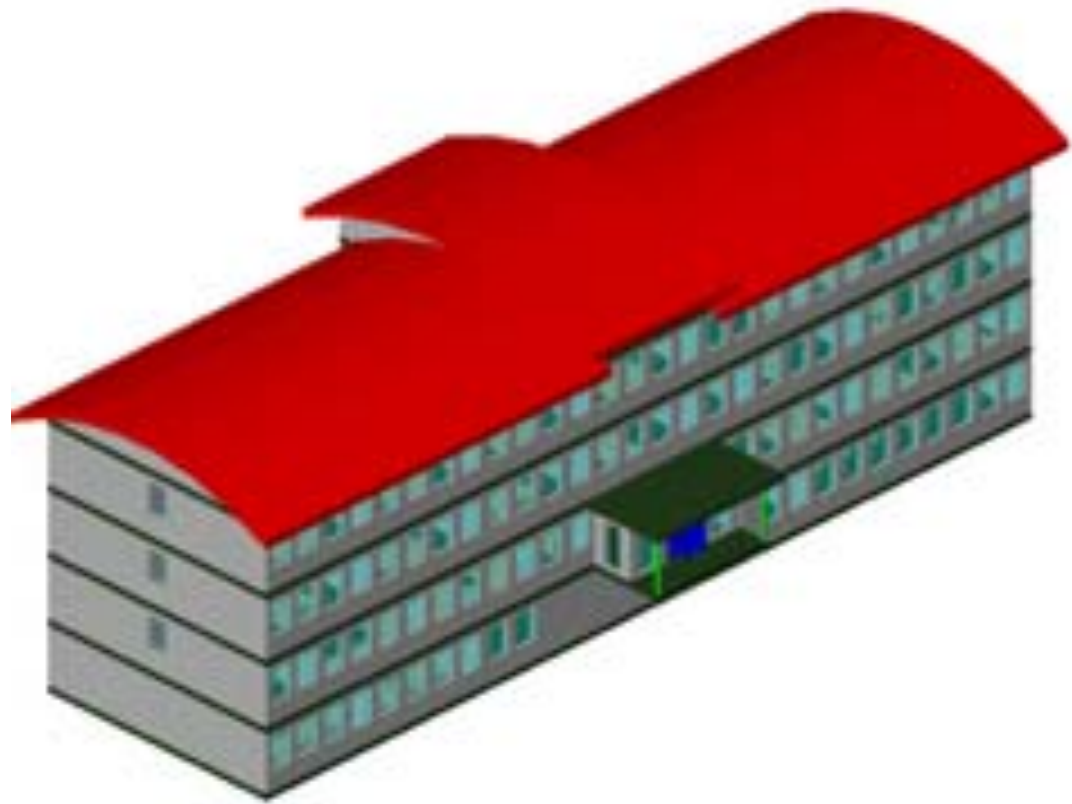


(c) output CityGML

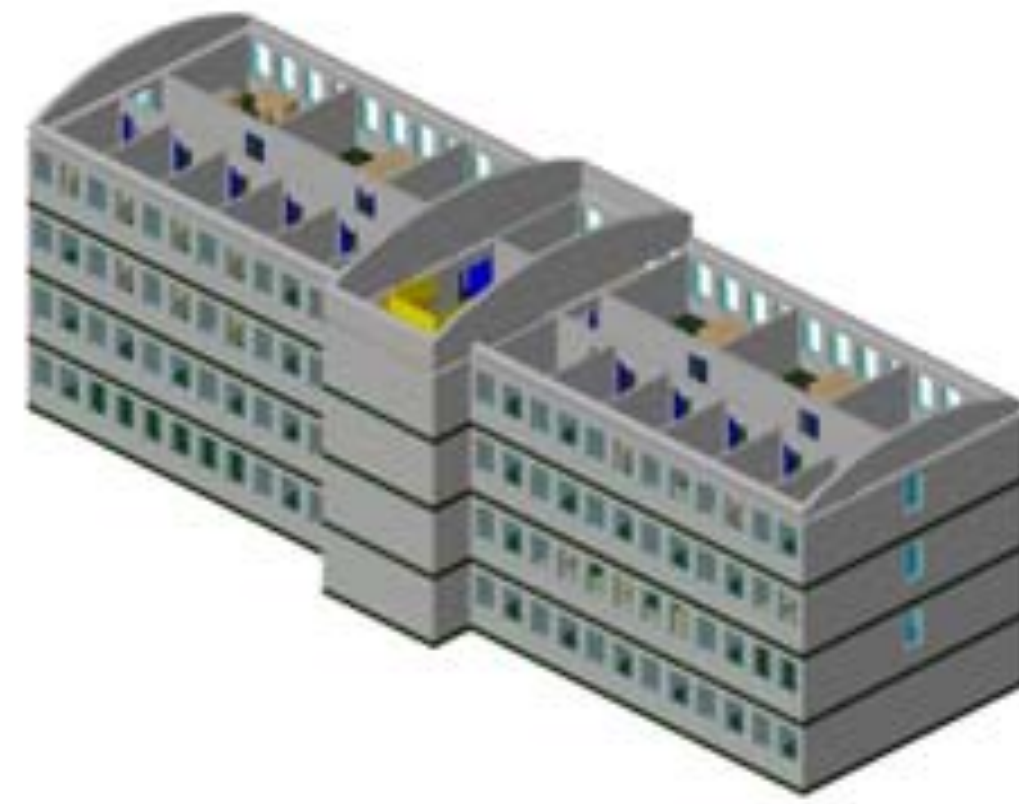


(d) CityGML without roof

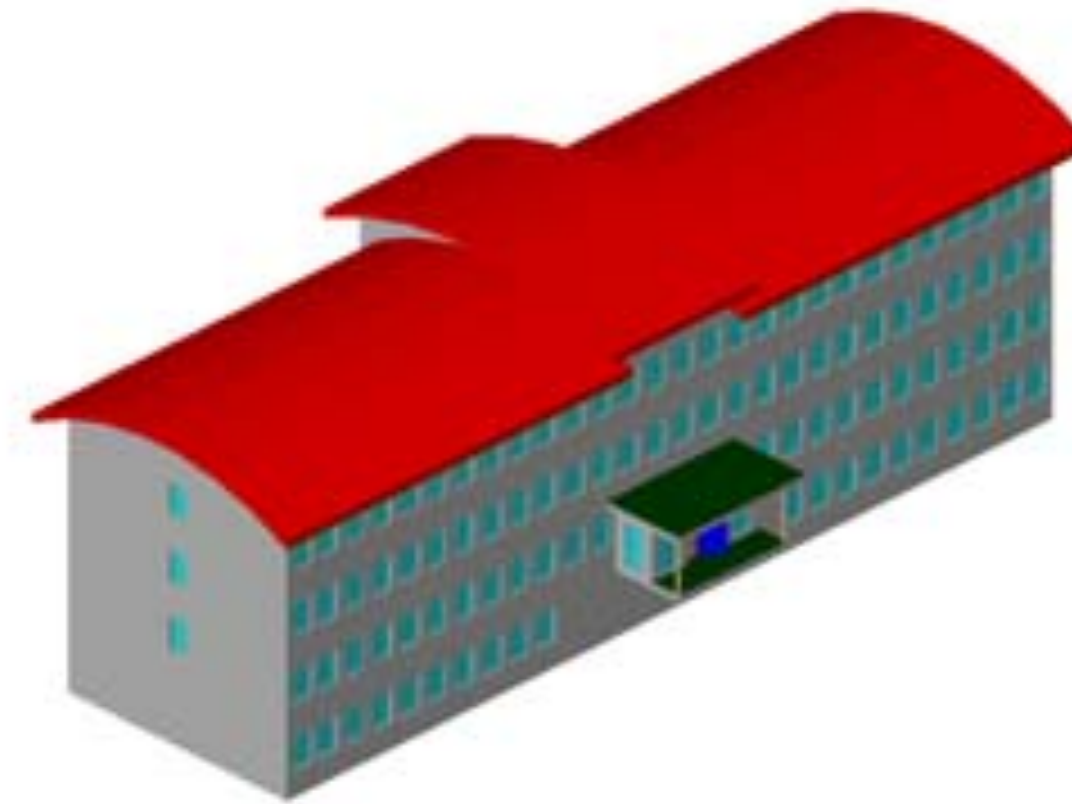
Results



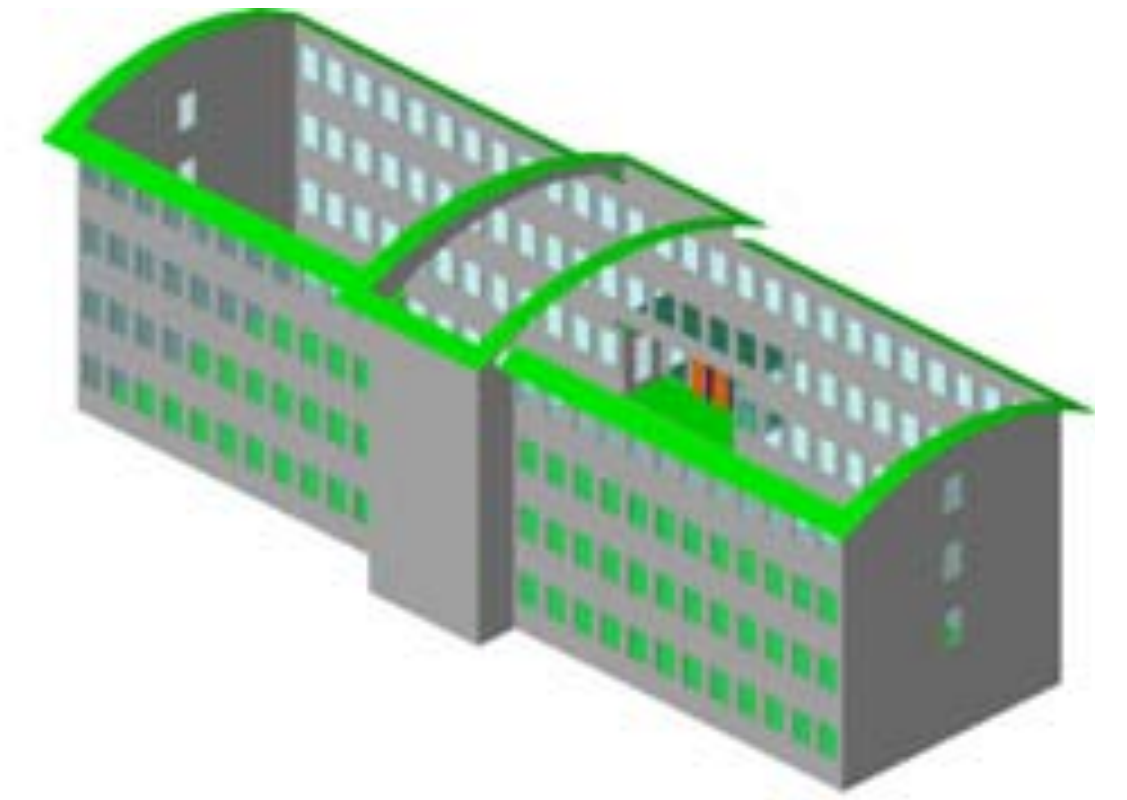
(a) input IFC



(b) IFC without roof

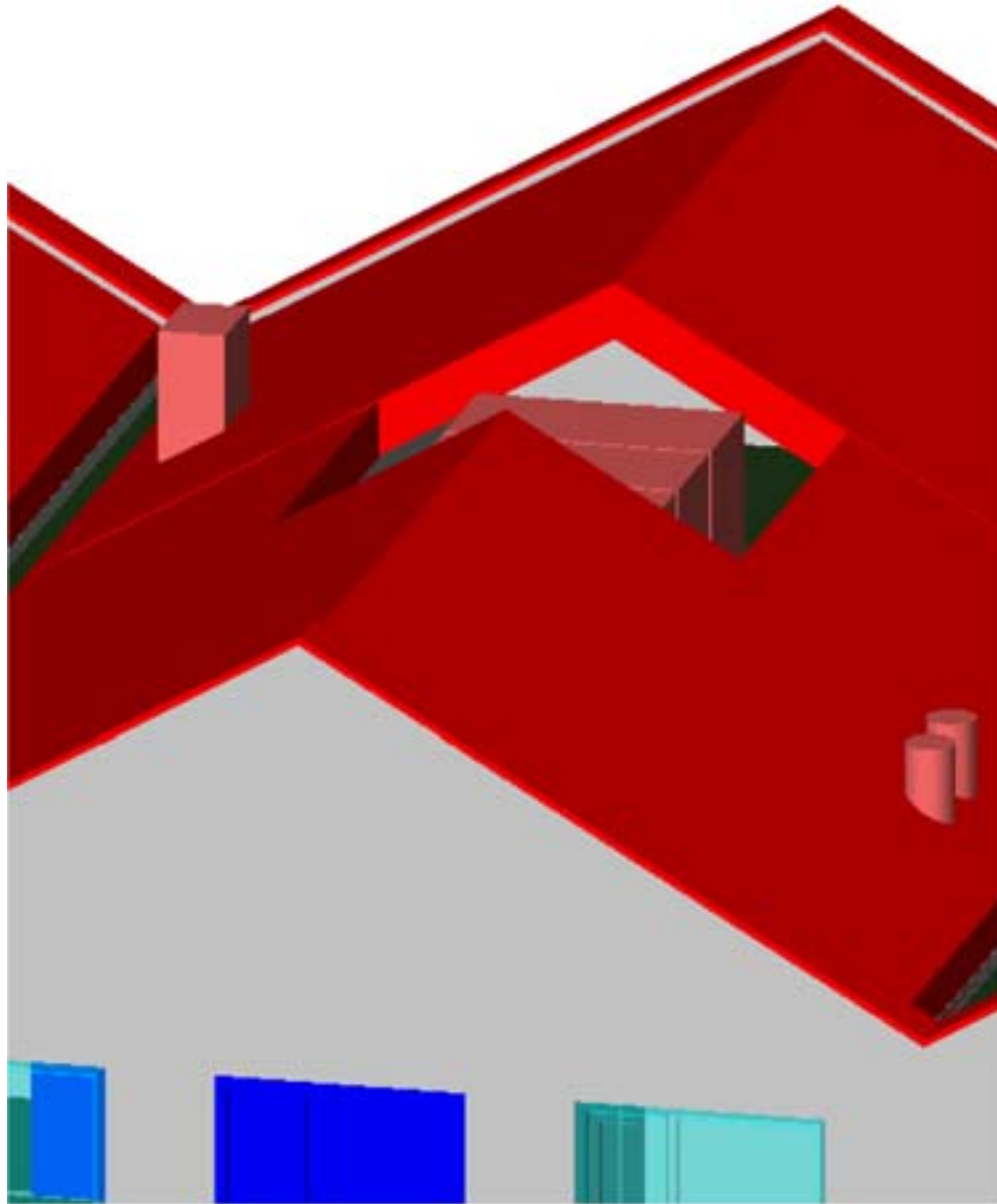


(c) output CityGML

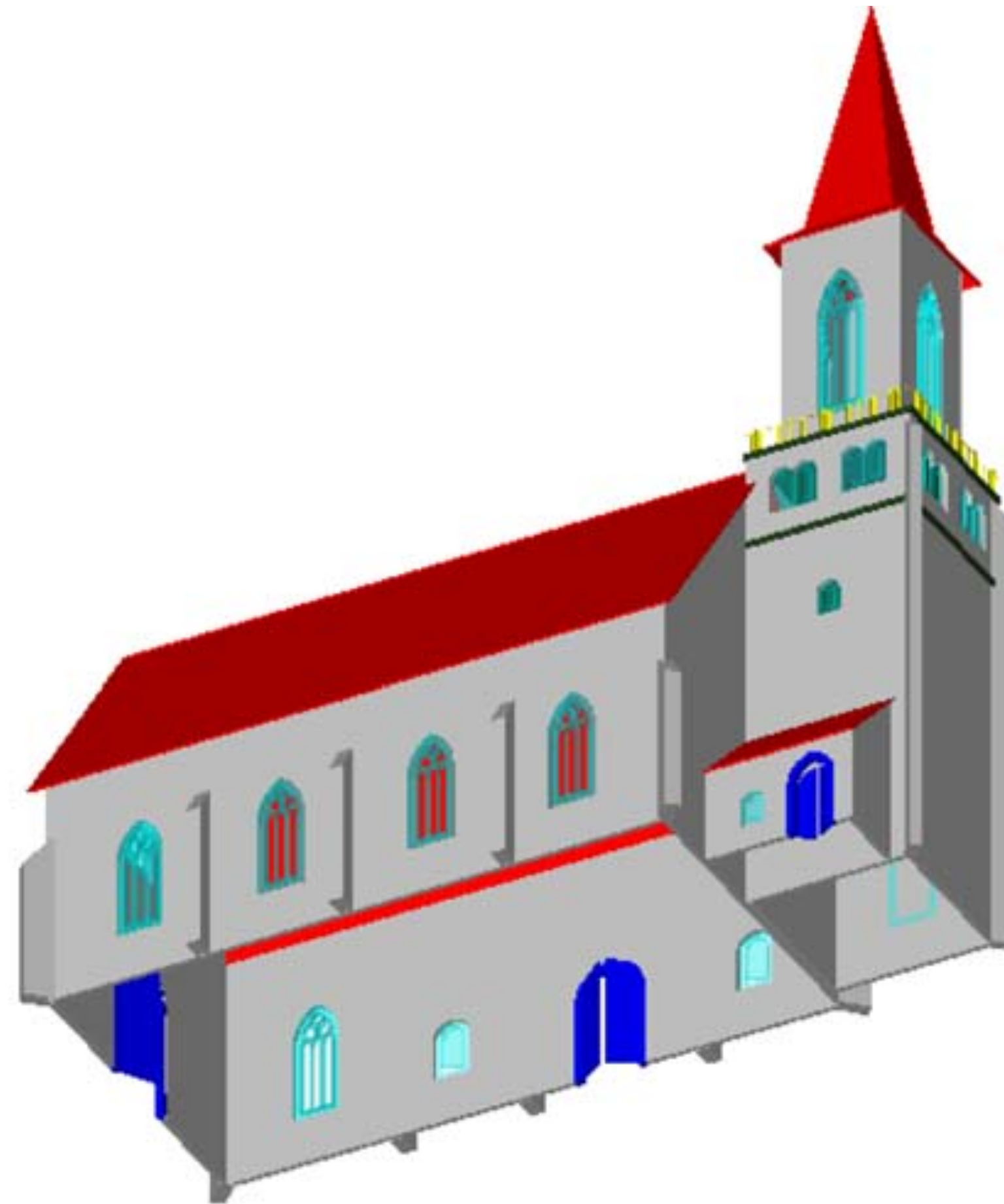


(d) CityGML without roof

Issues



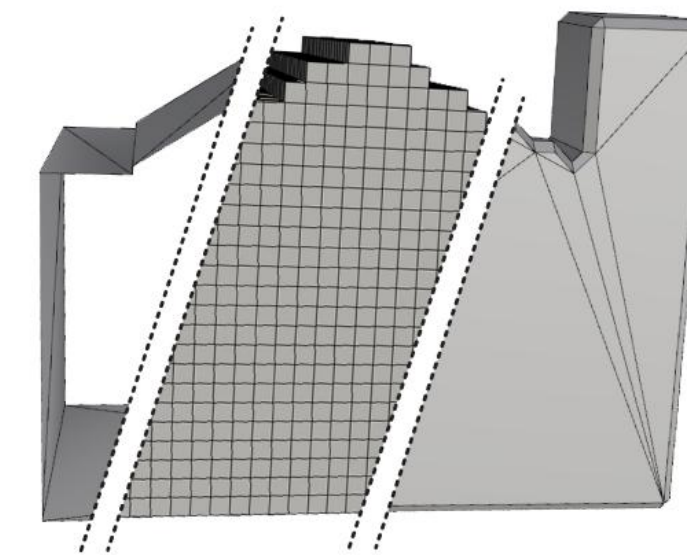
(a) Building where part of the roof is missing



(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

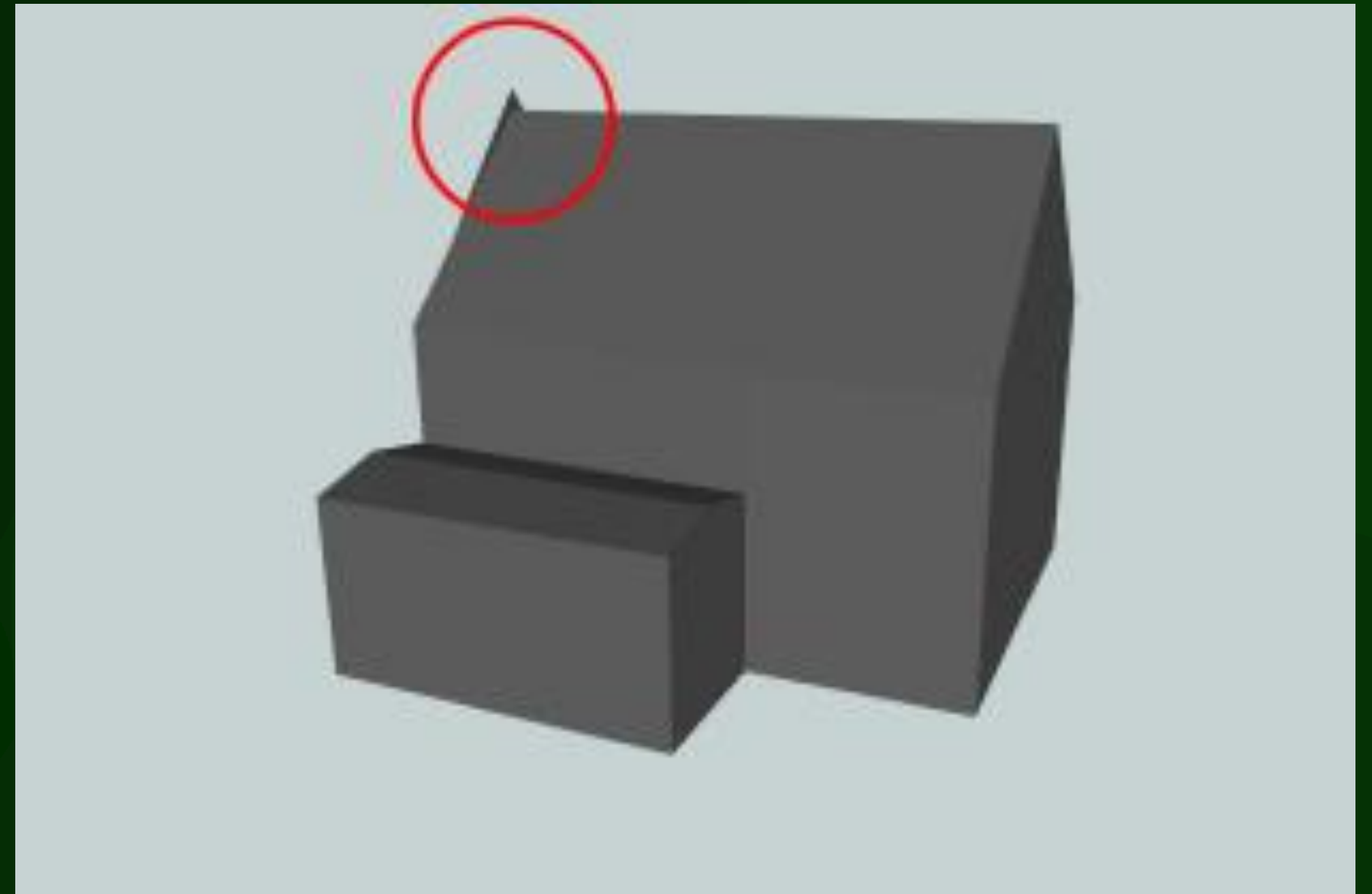
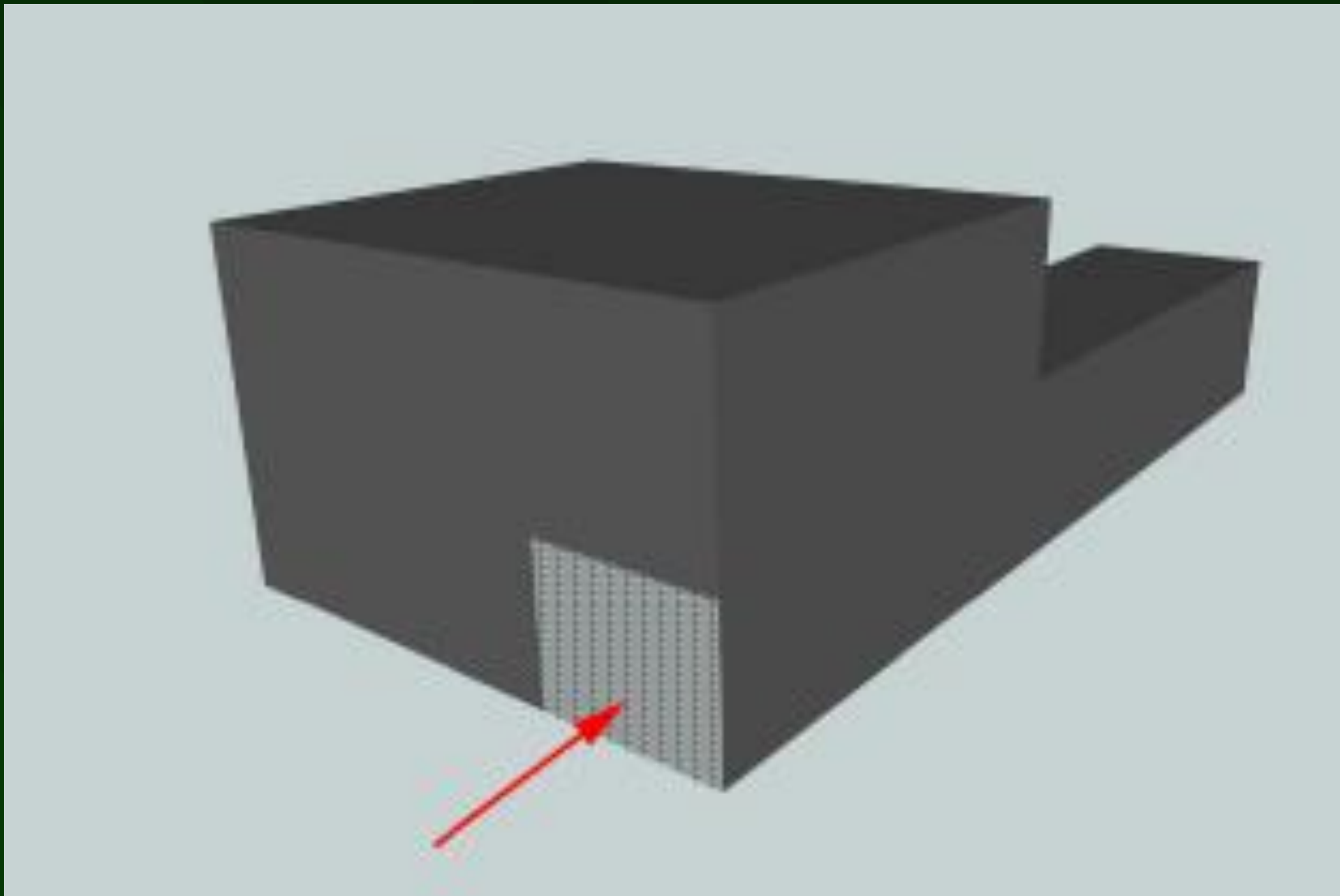
by

Damien Mulder

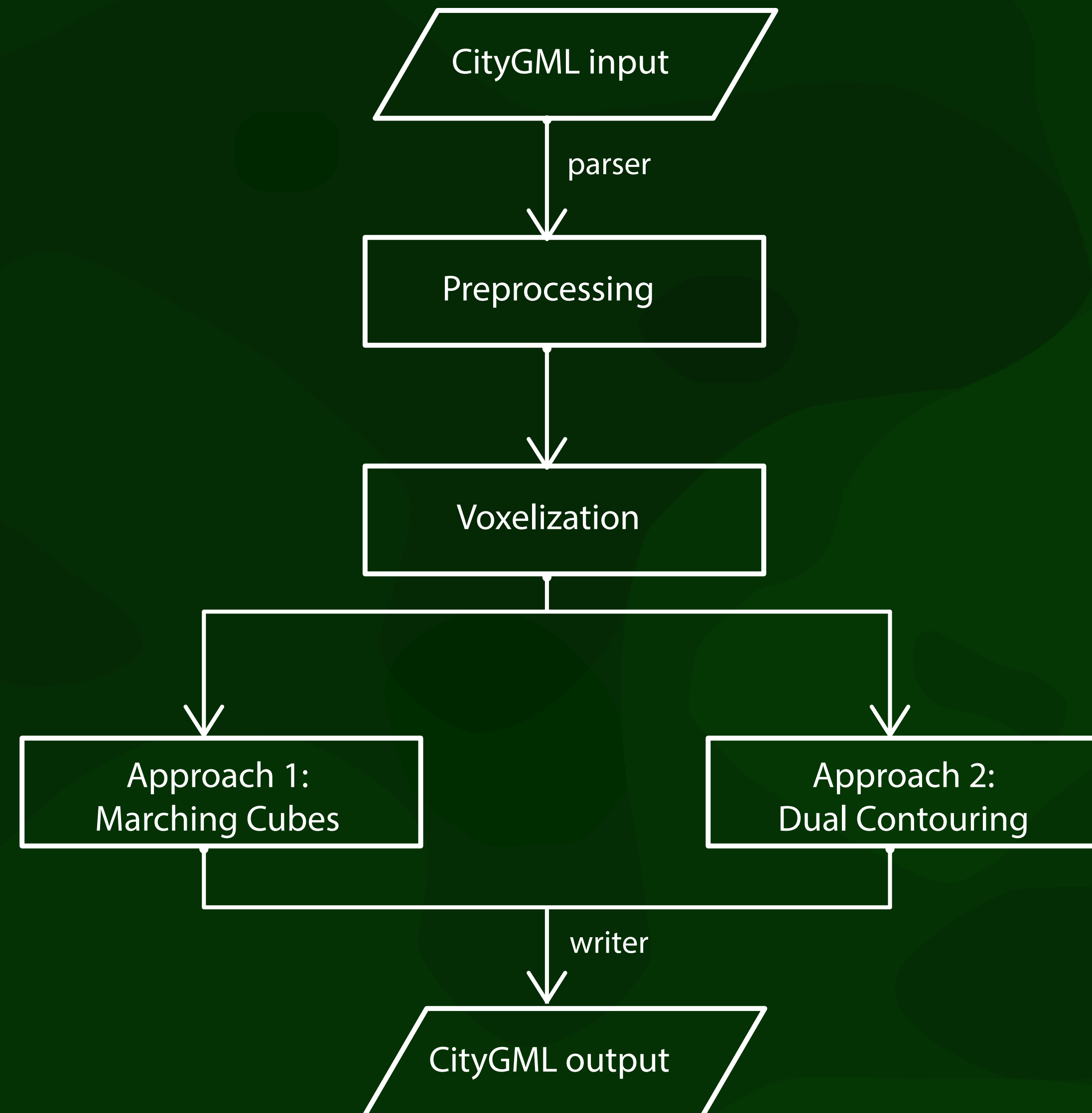
M.Sc Geomatics Thesis

June 2015

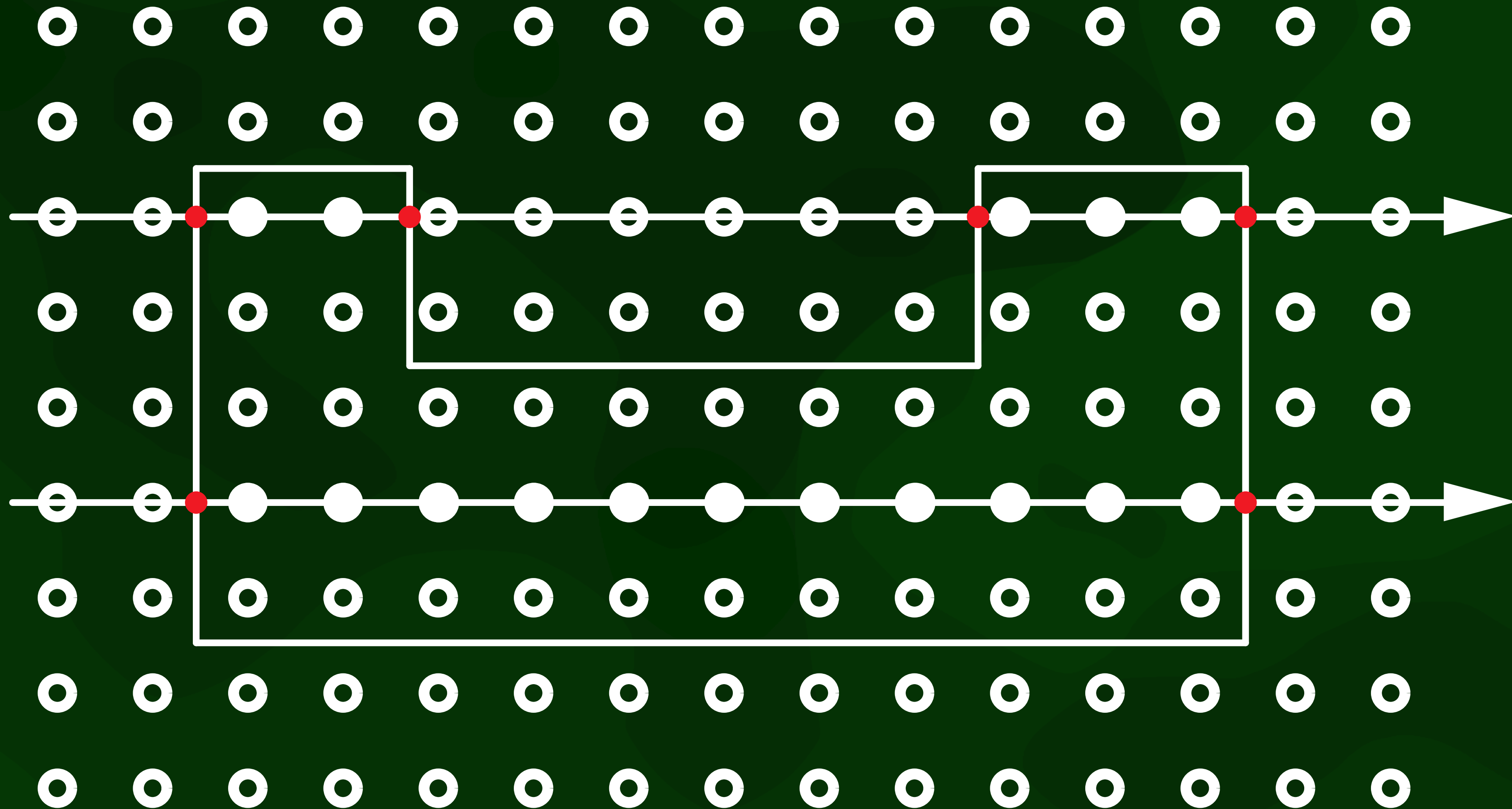
Fixing 3D models



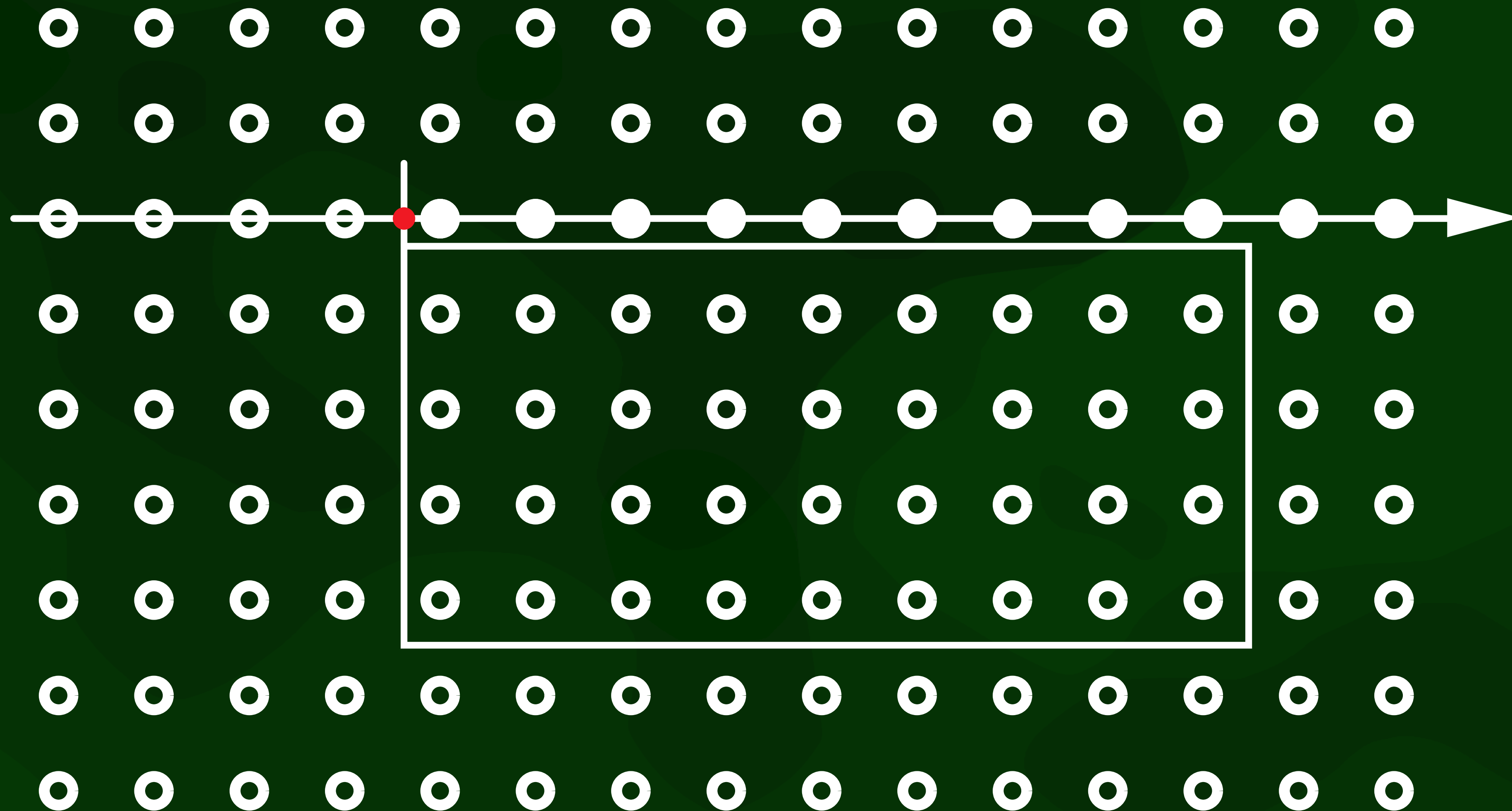
Methodology



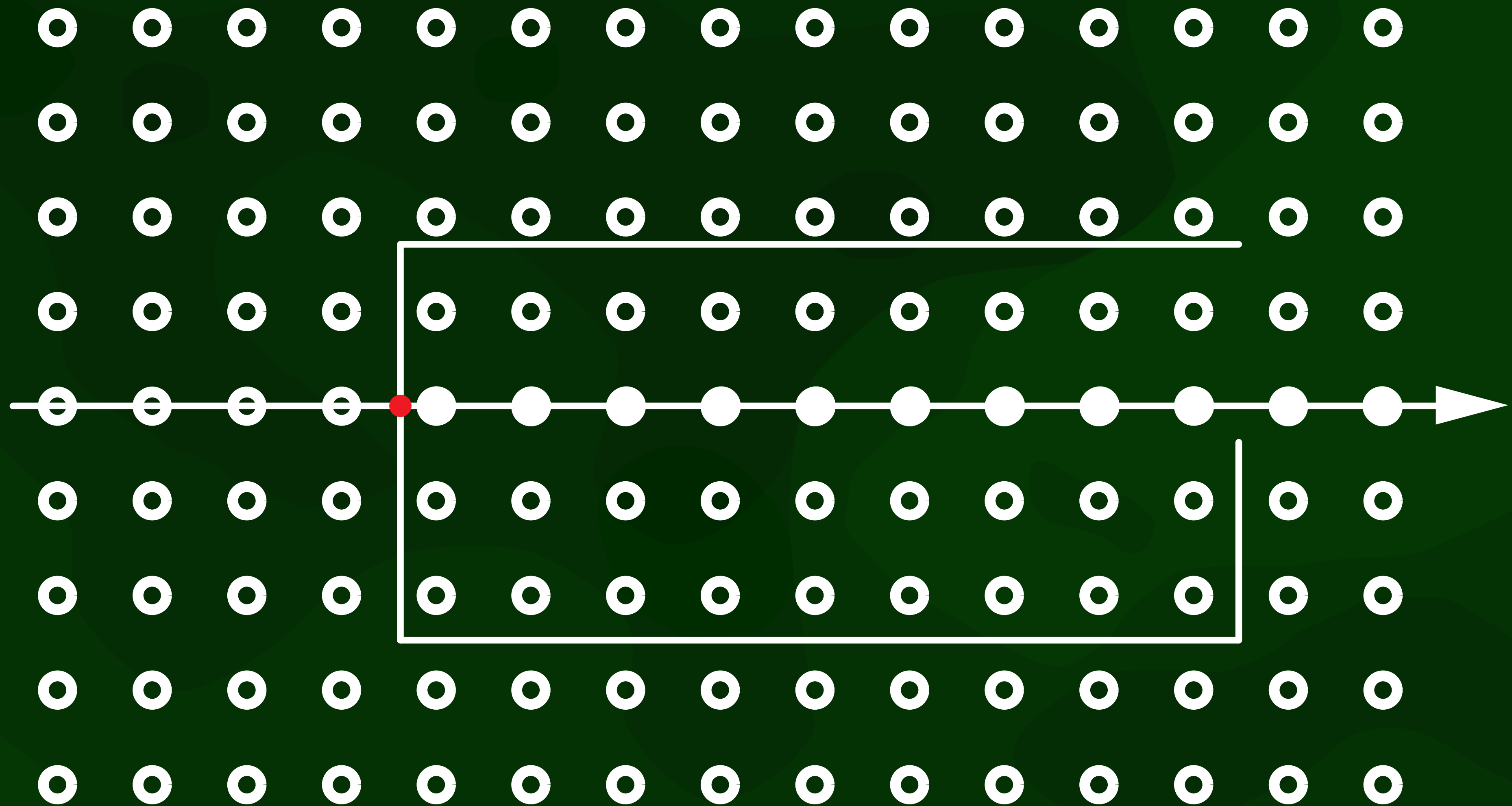
Voxelisation



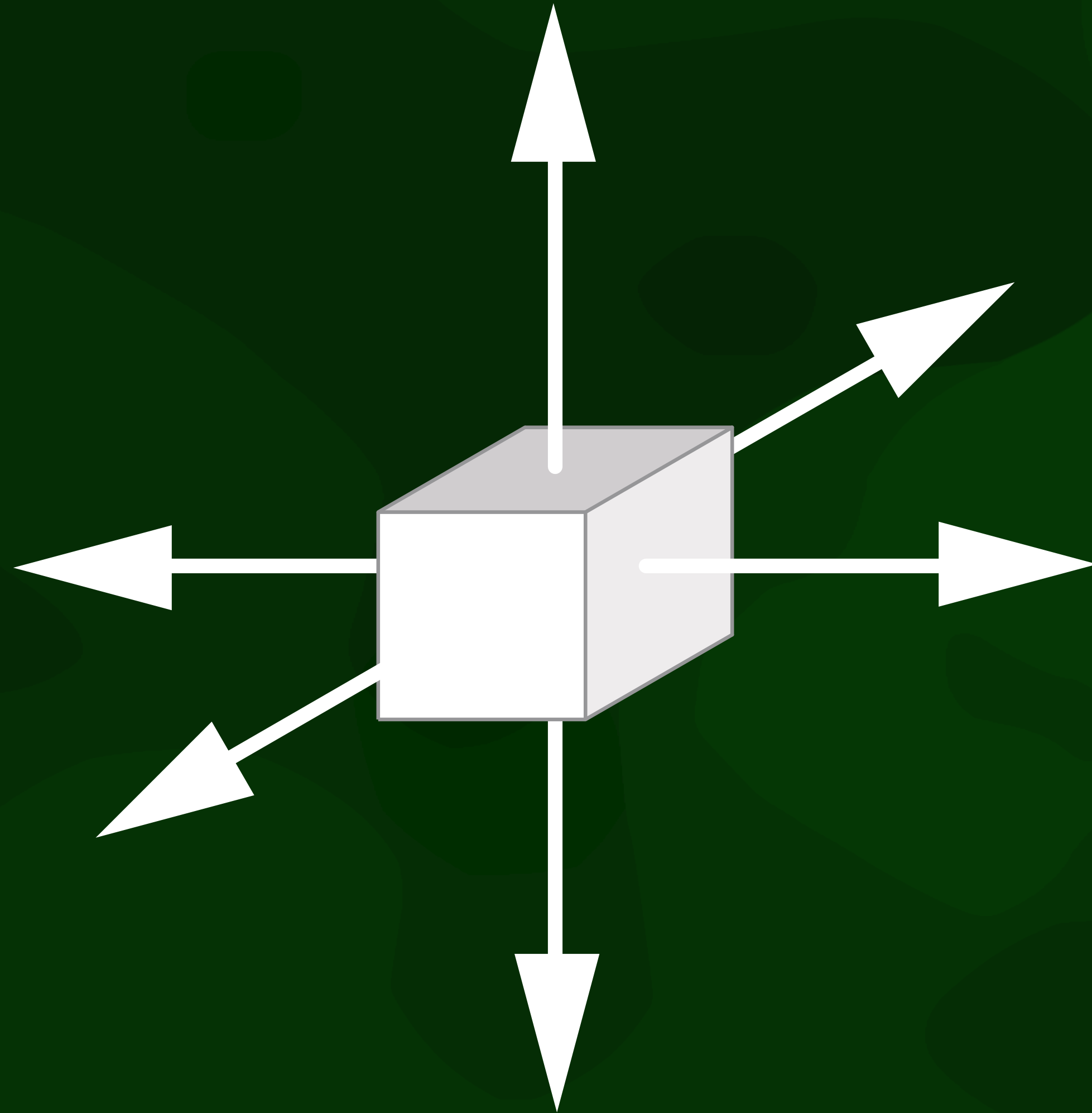
Voxelisation: overshoot



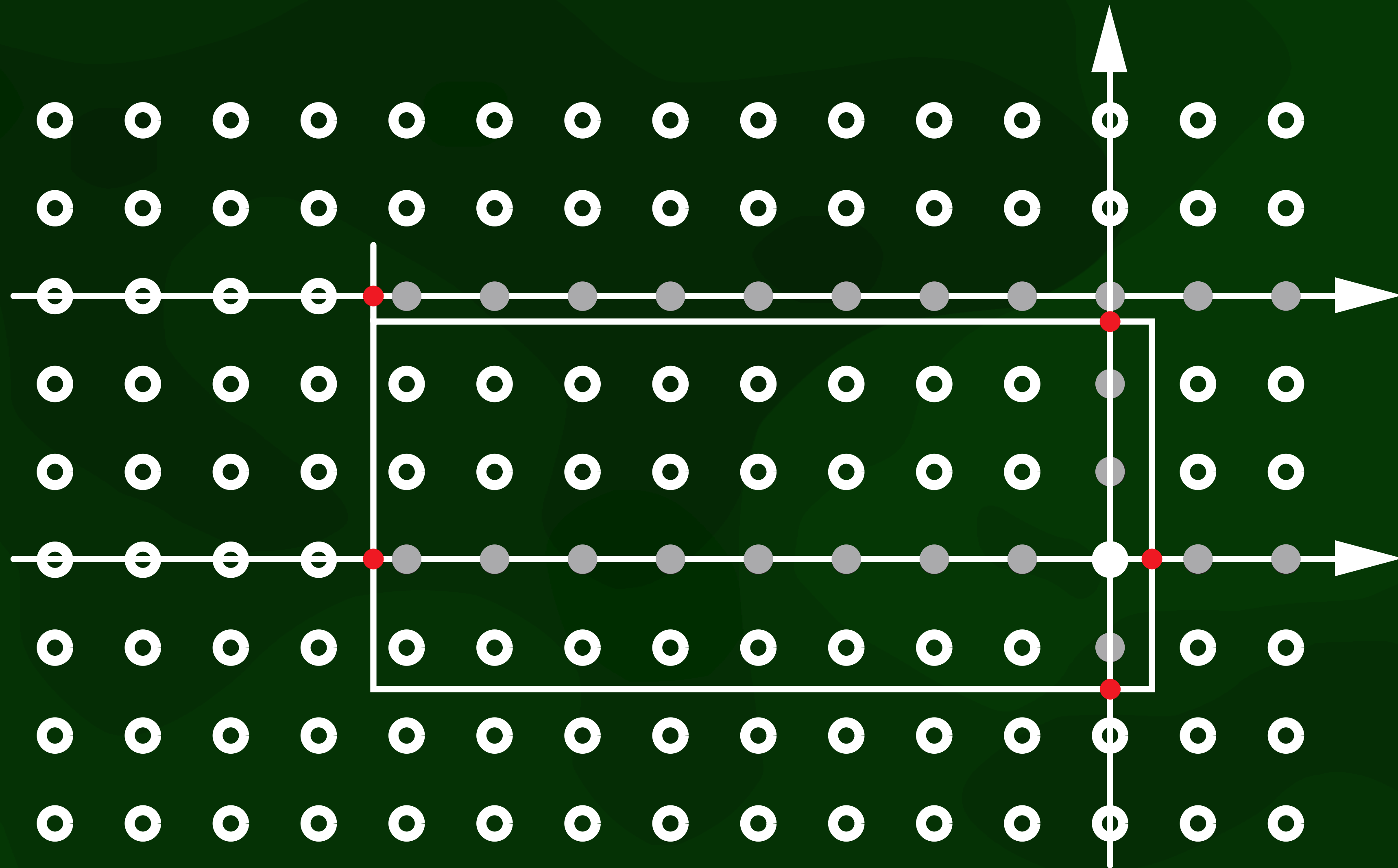
Voxelisation: gap



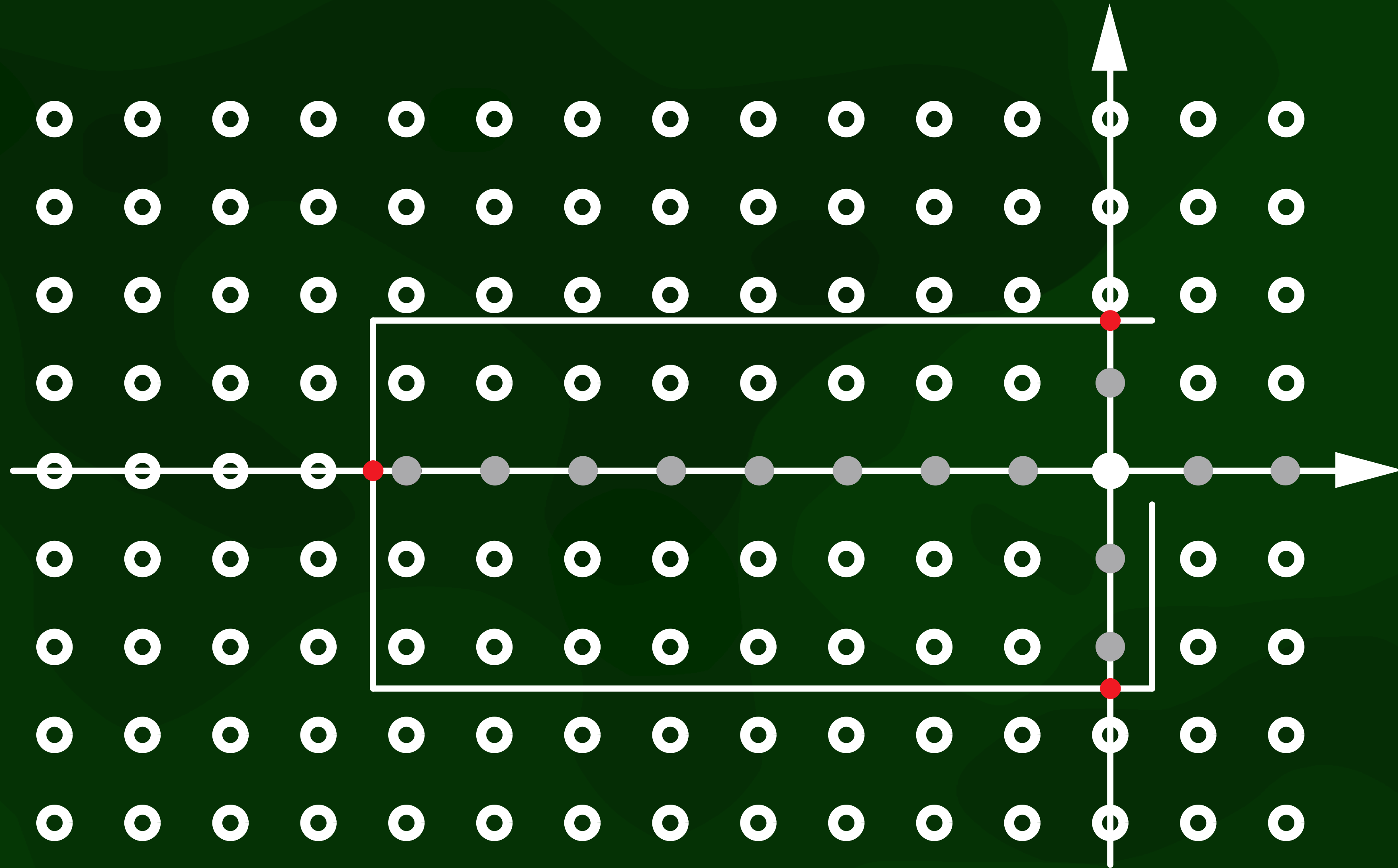
Voxelisation: shooting rays



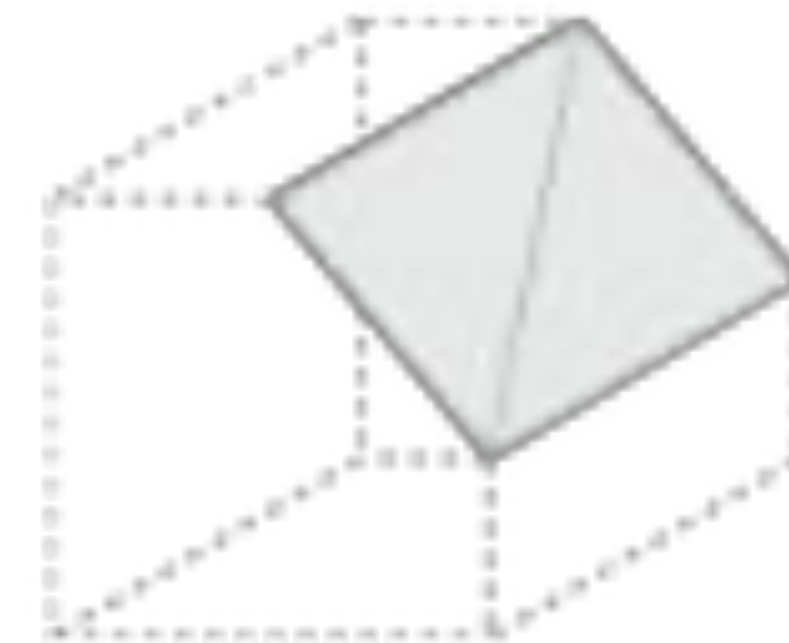
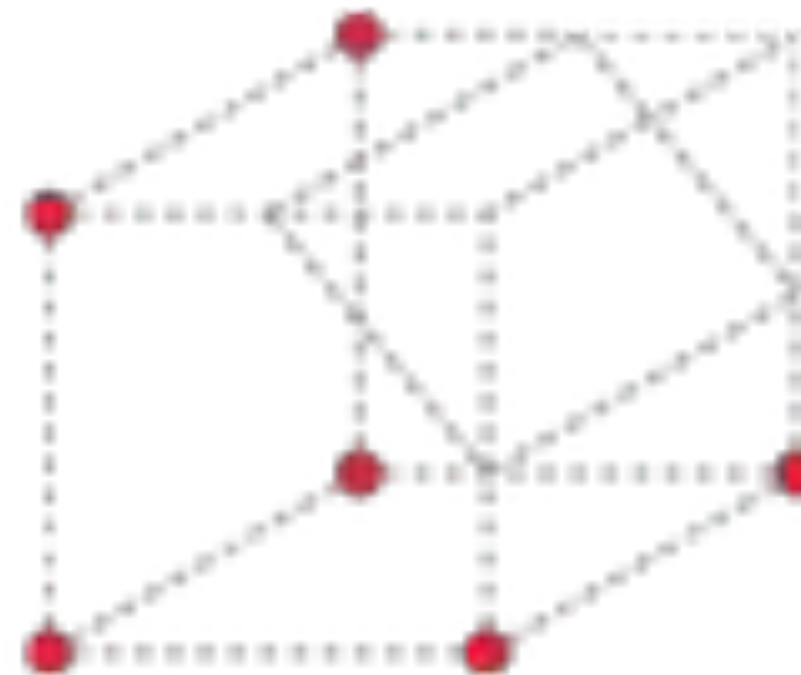
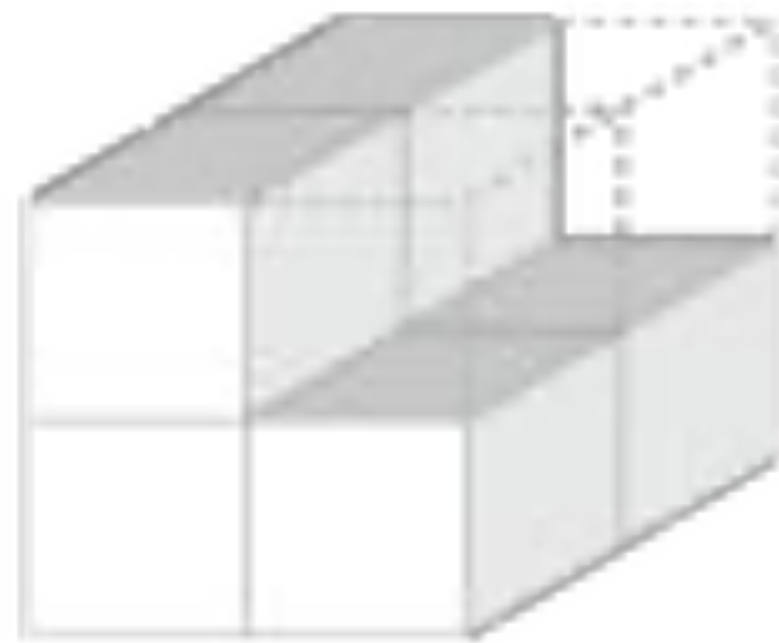
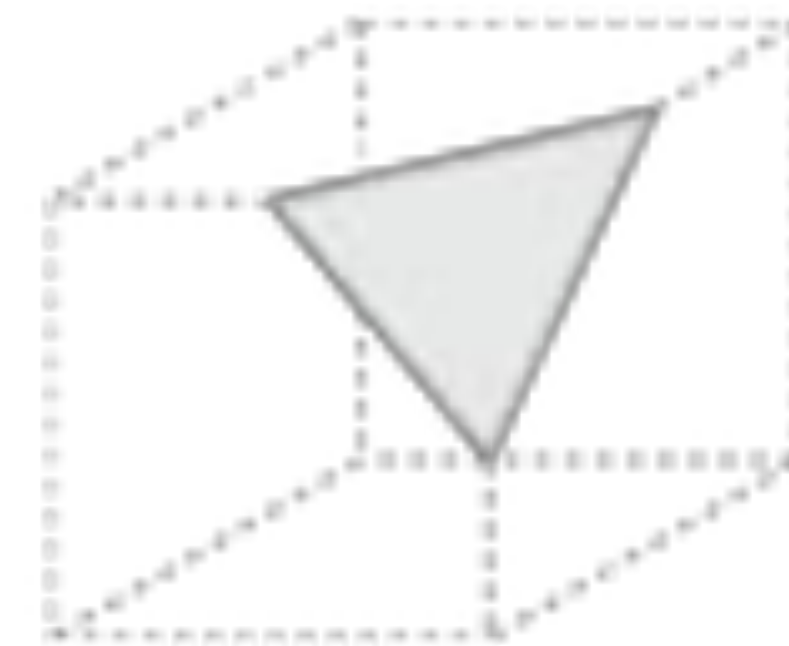
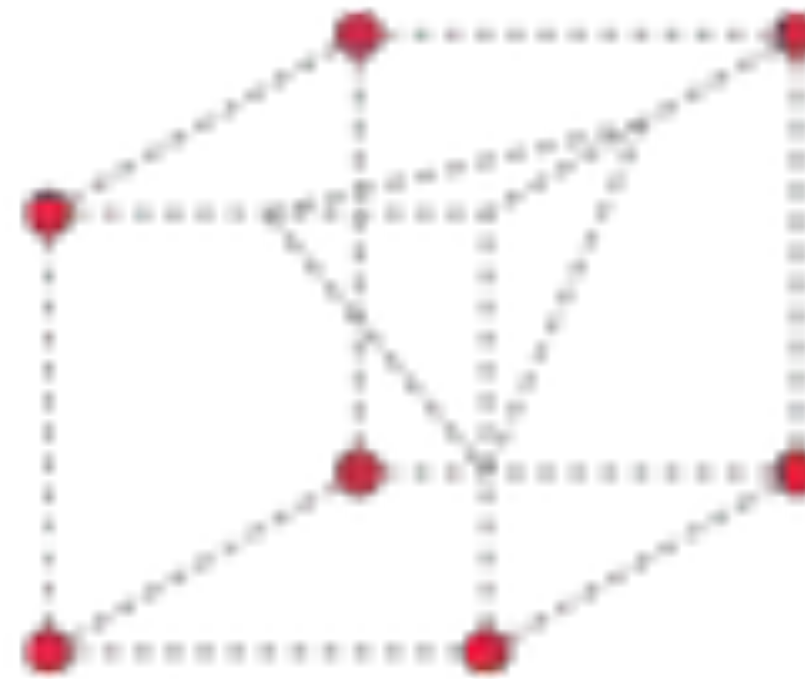
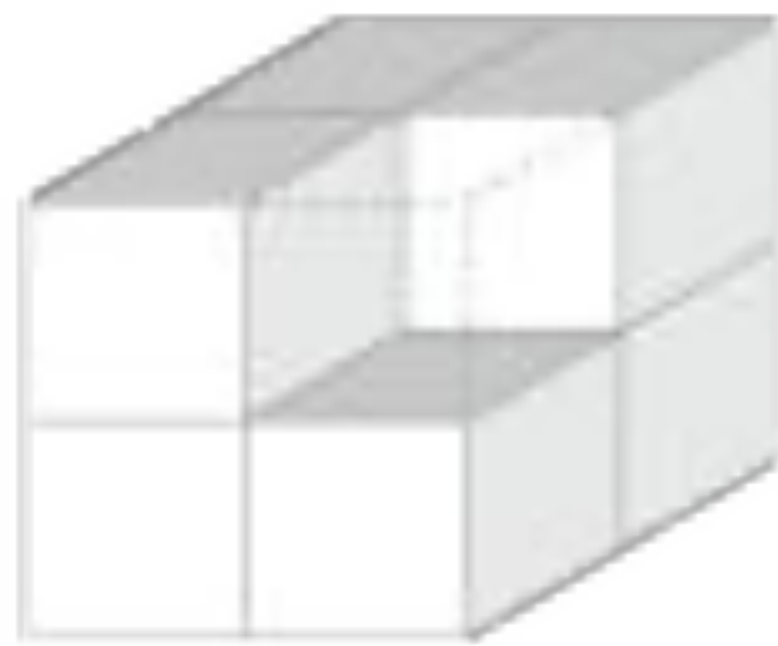
Majority counting: overshoot



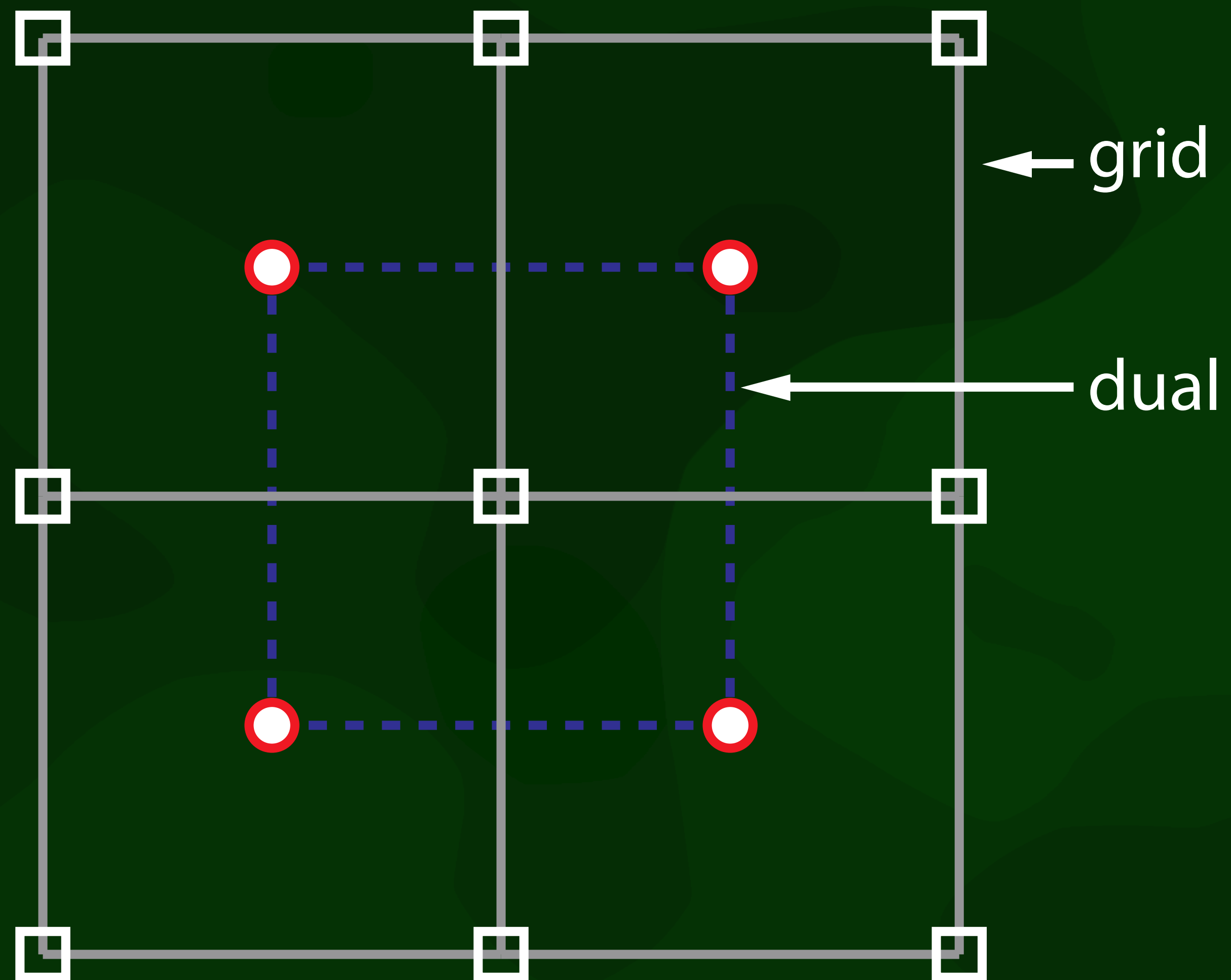
Majority counting: gap



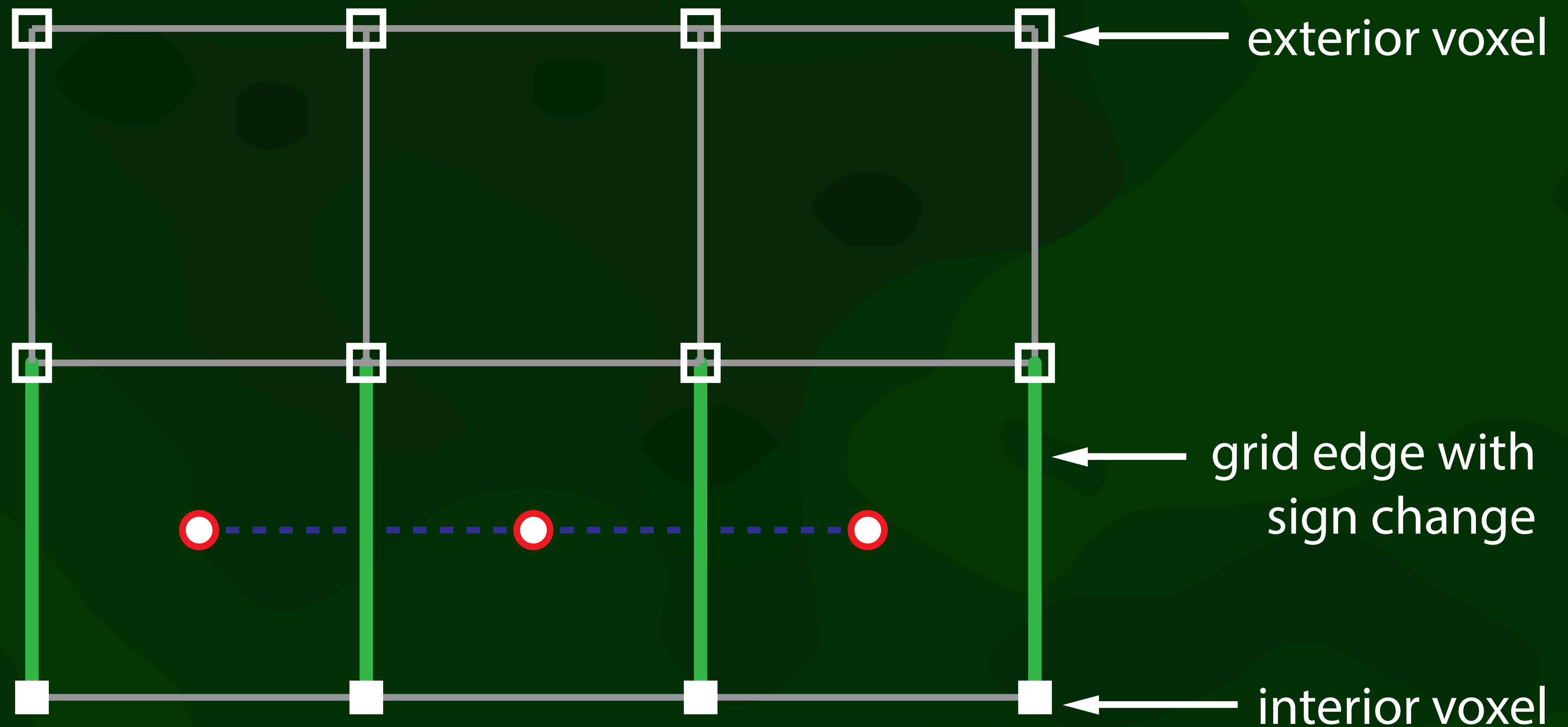
Marching cubes



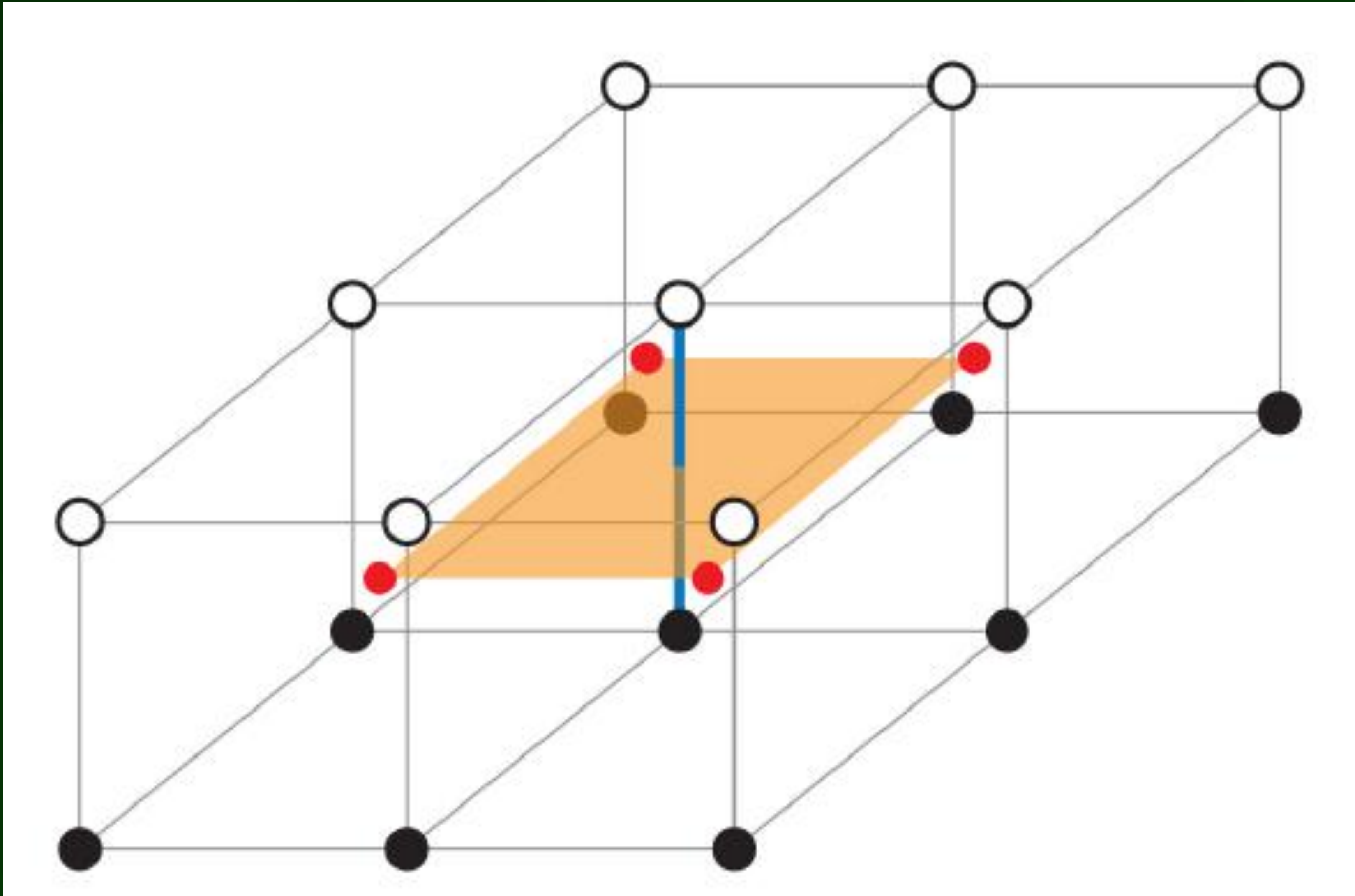
Dual contouring



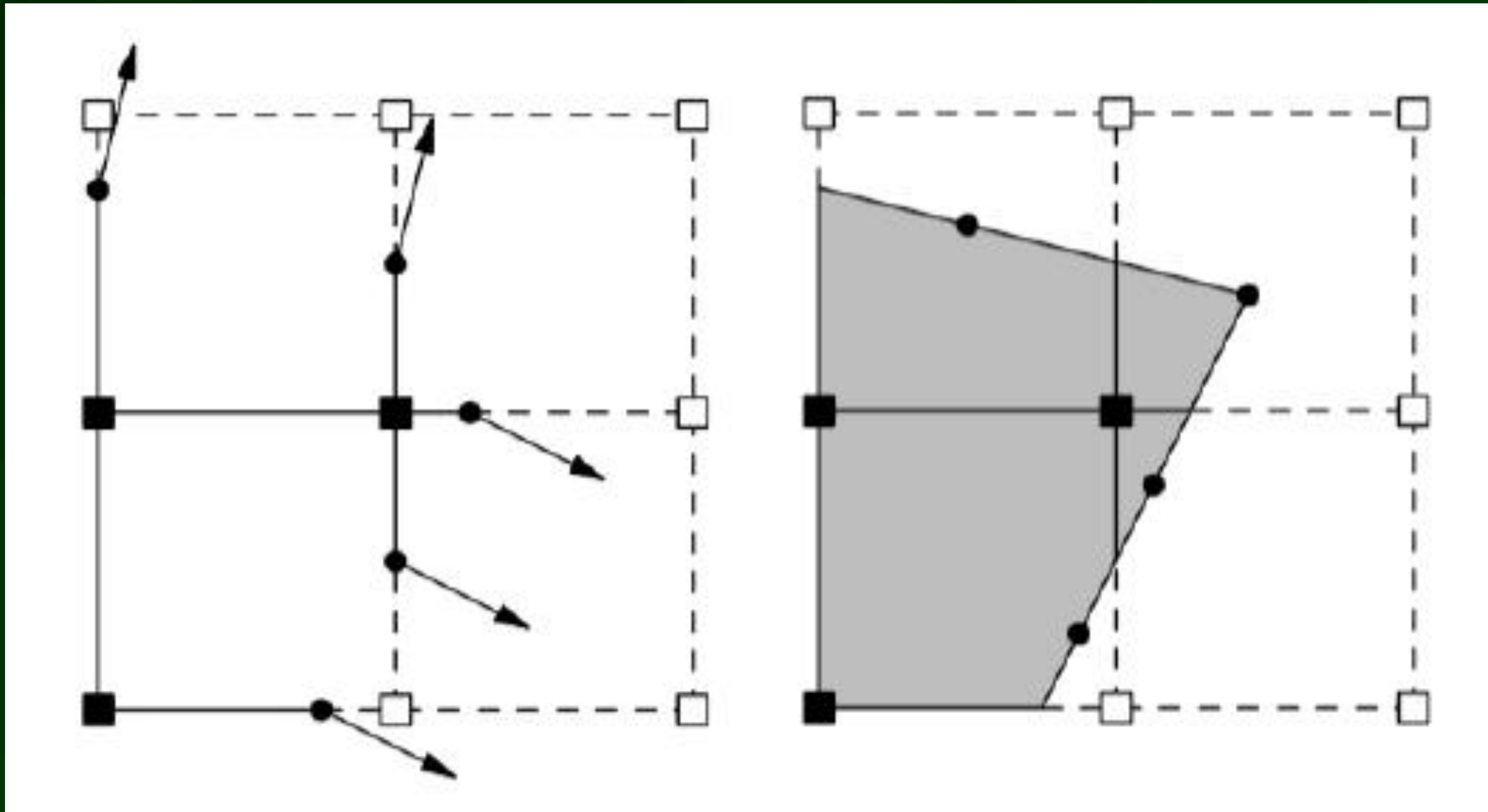
Dual contouring



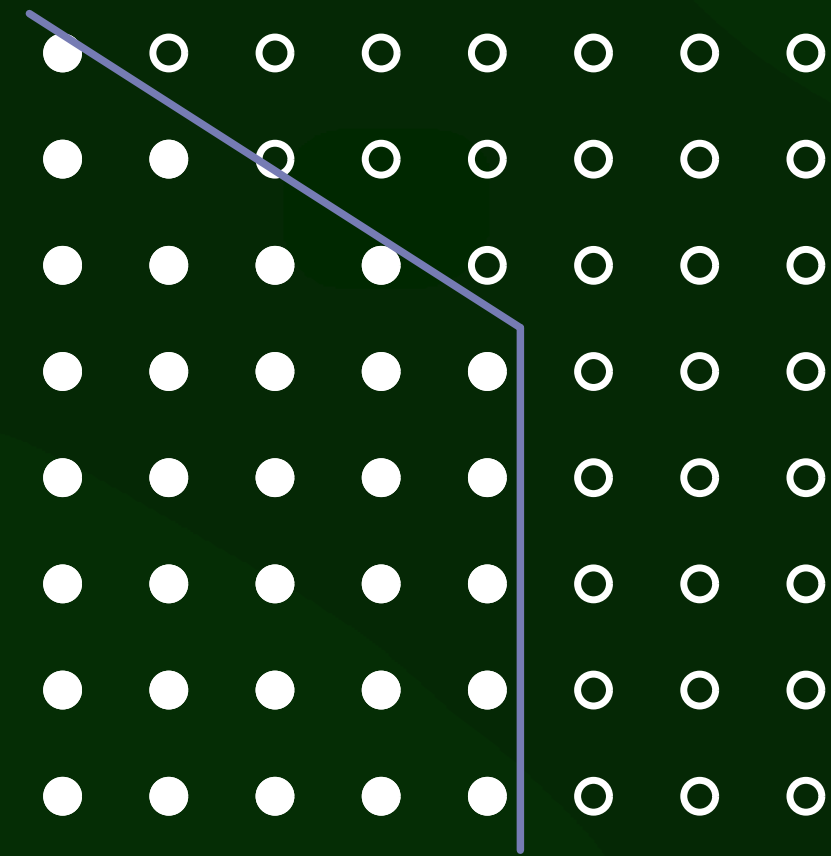
Dual contouring



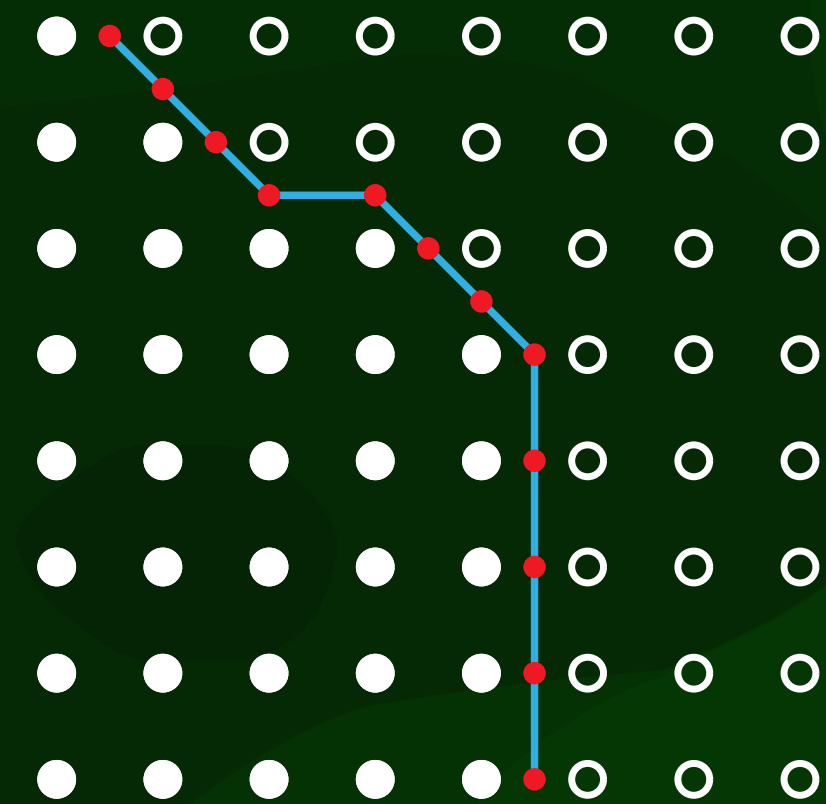
Dual contouring



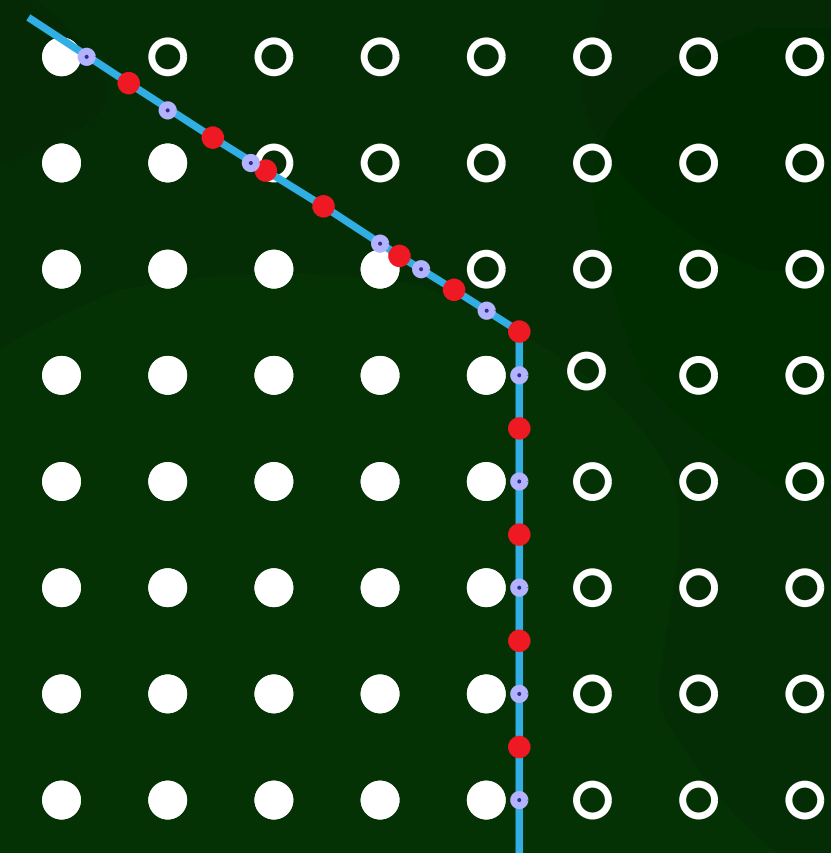
Full process



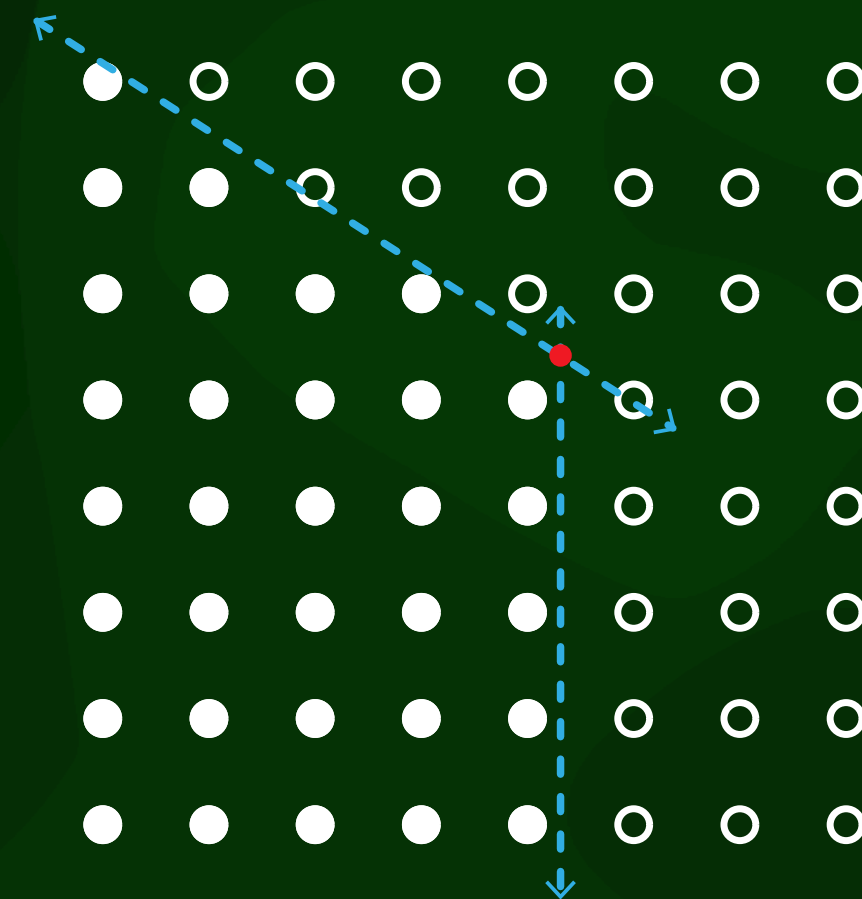
(a) The original polygonal model



(b) Marching Cubes result

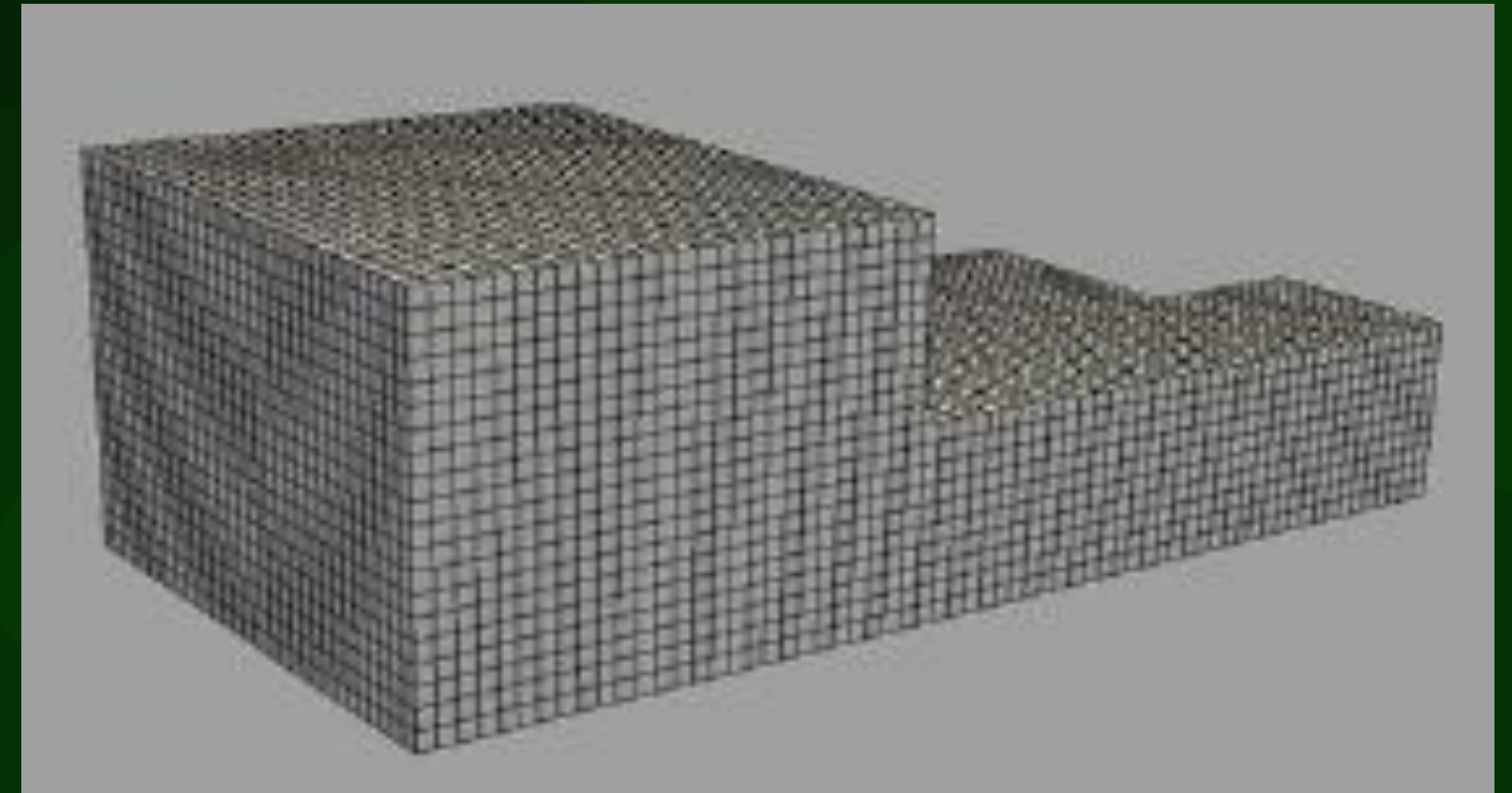
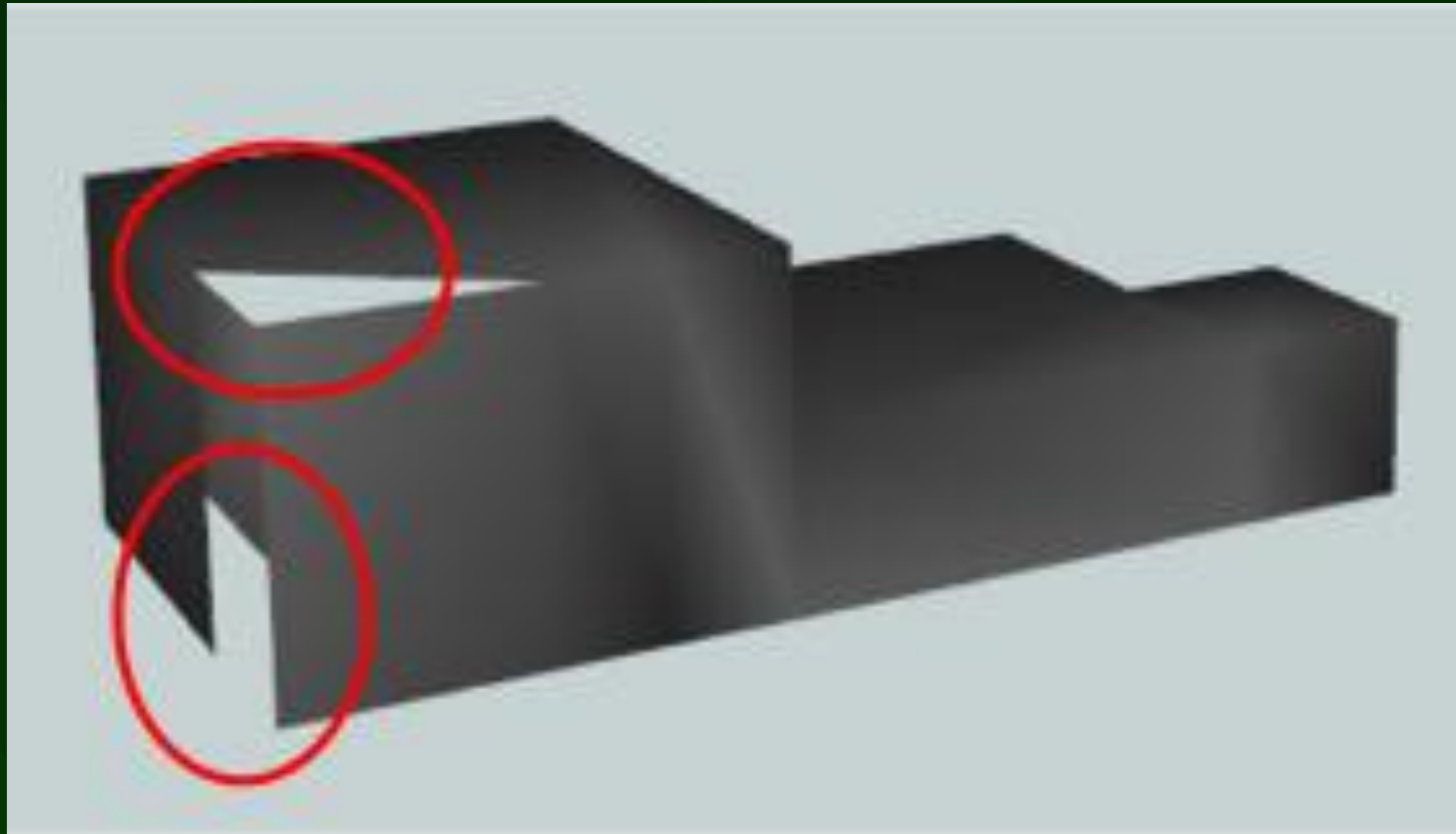


(c) Dual Contouring result

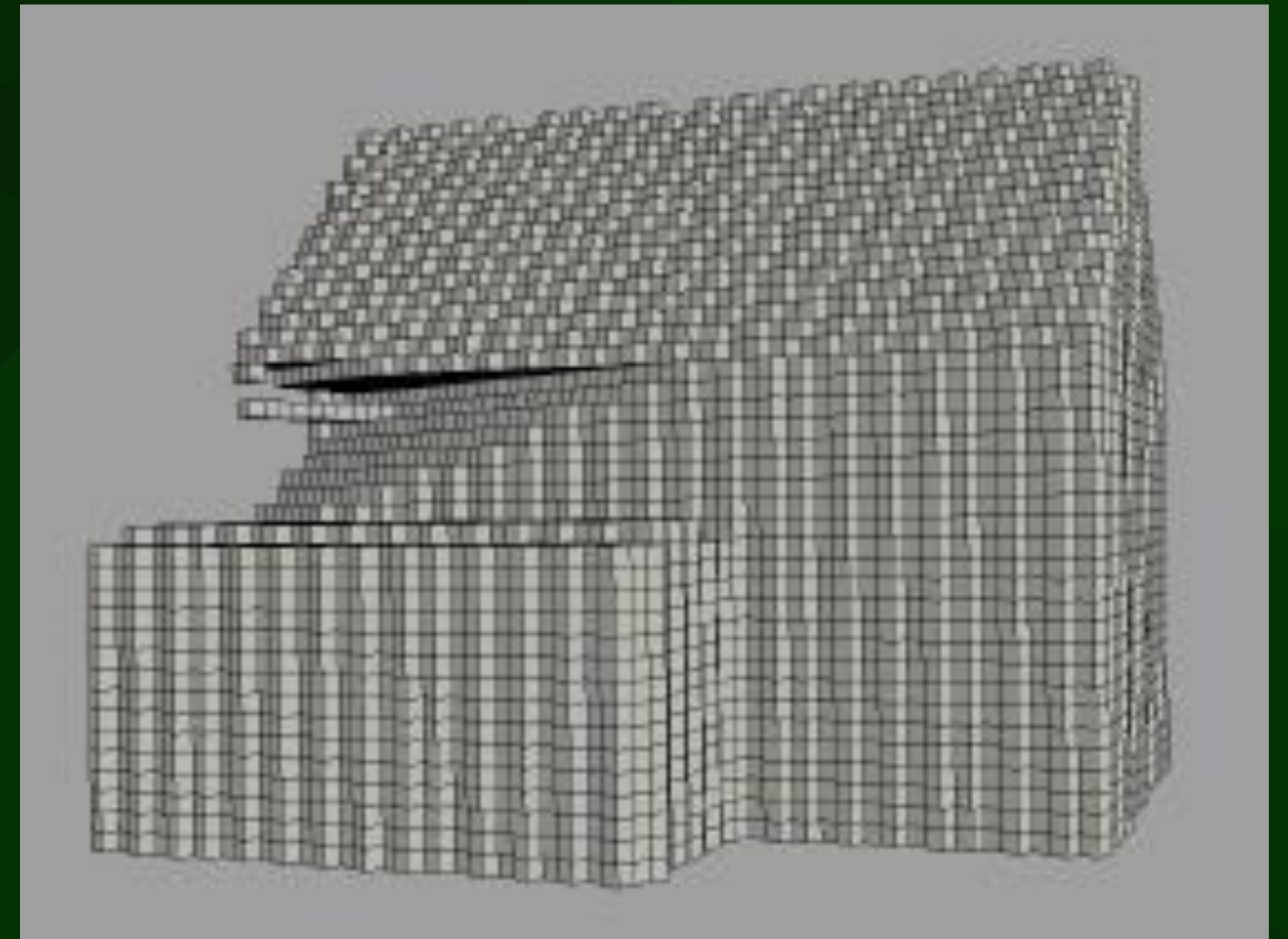
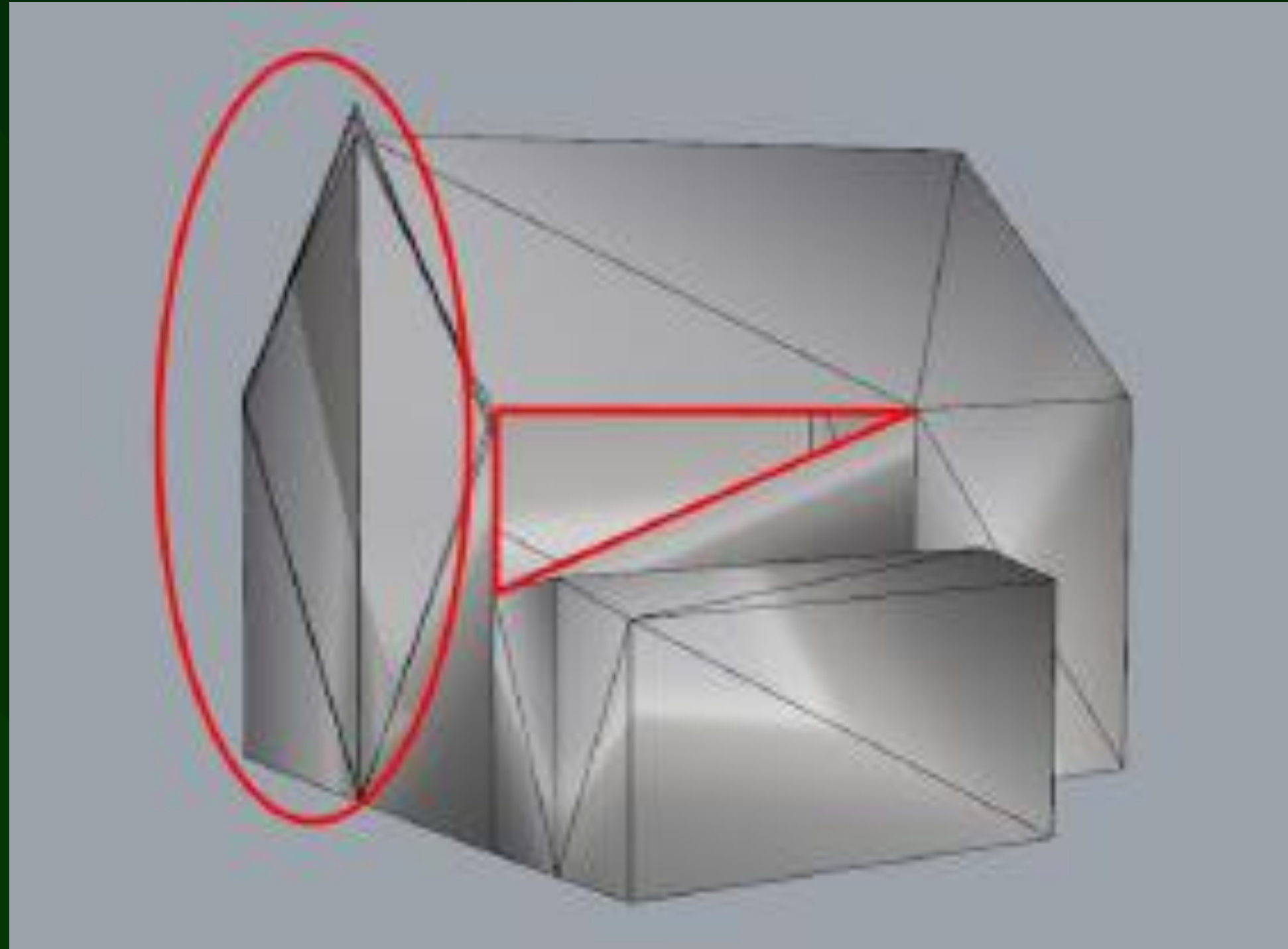


(d) Pressing result

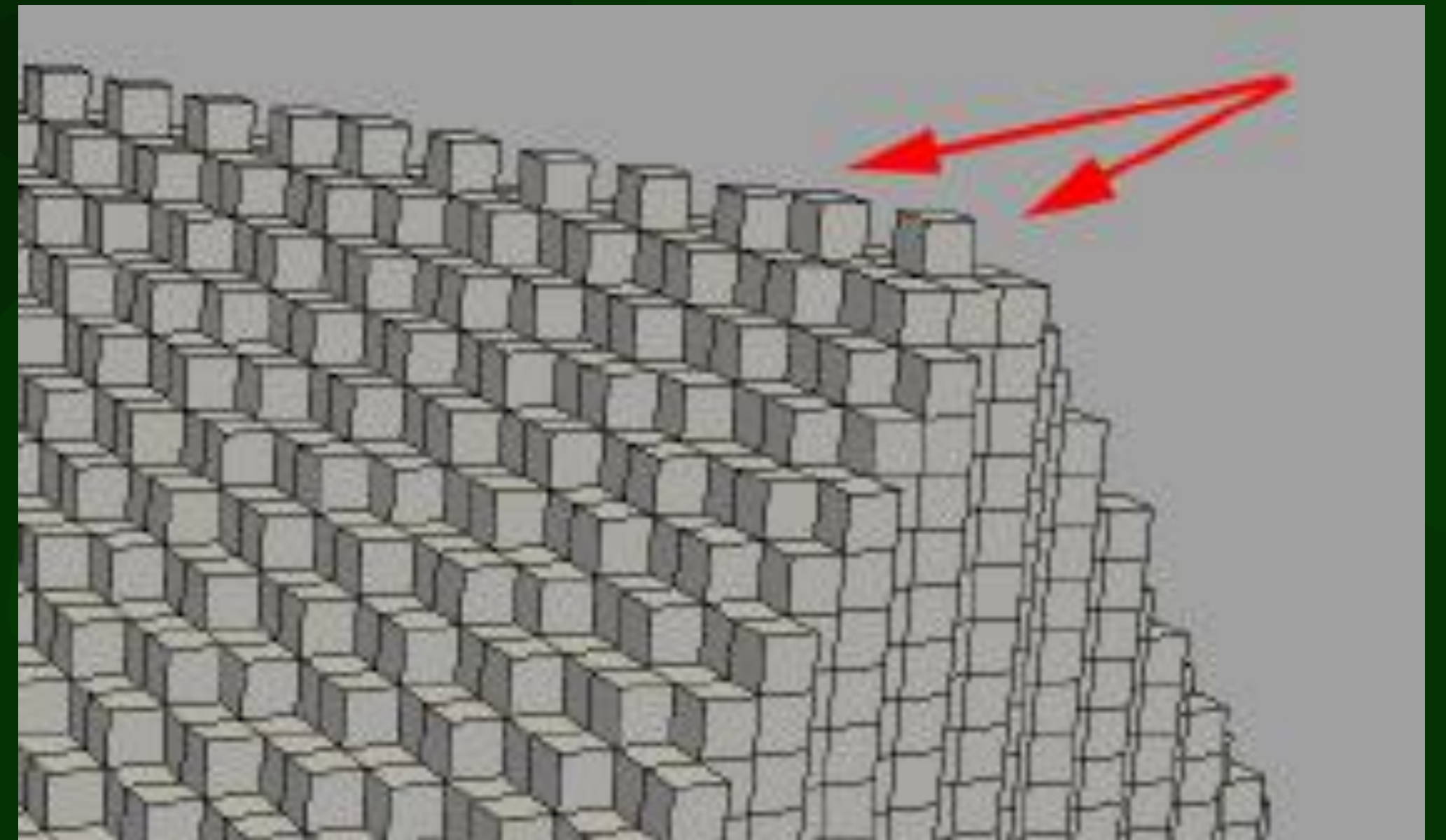
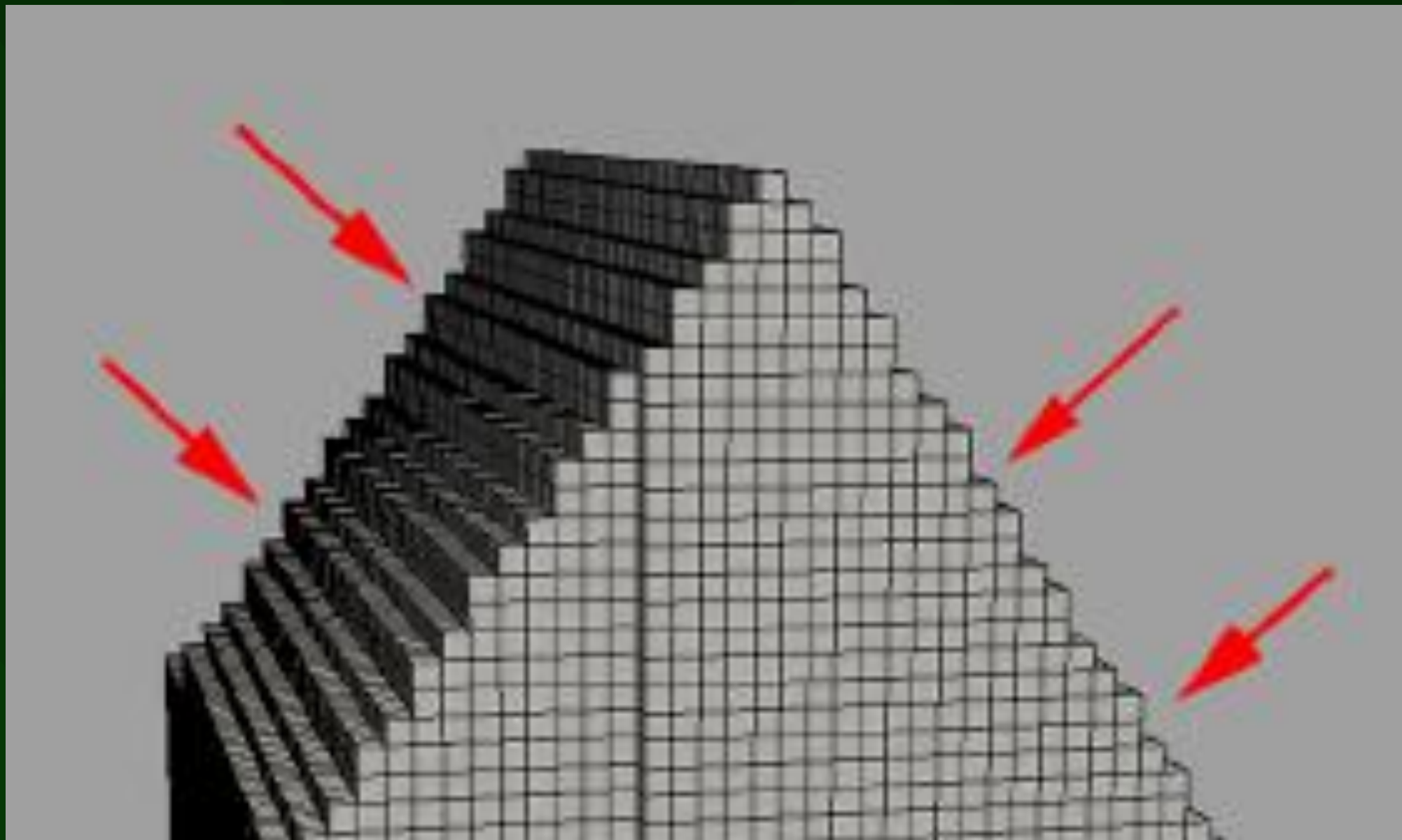
Results



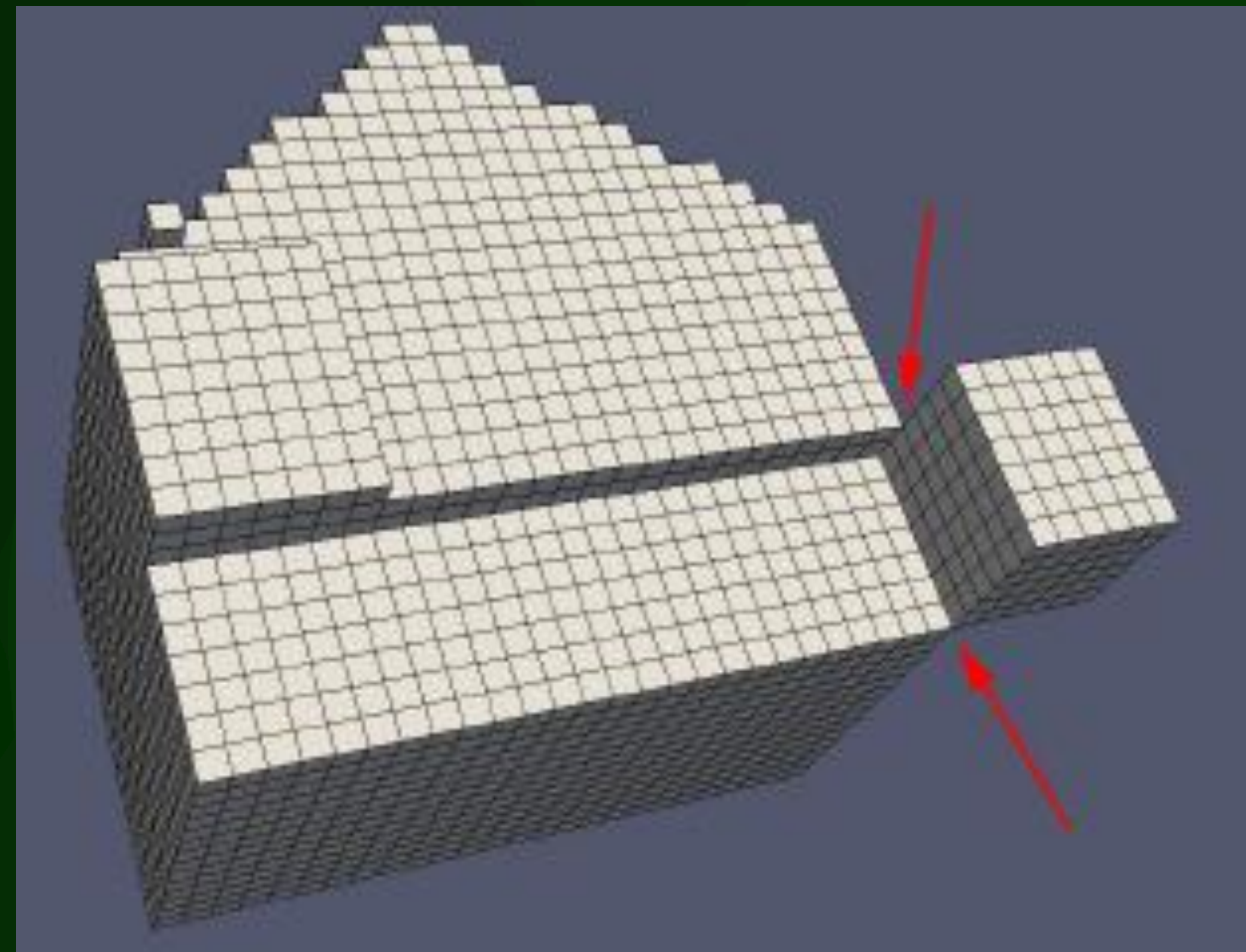
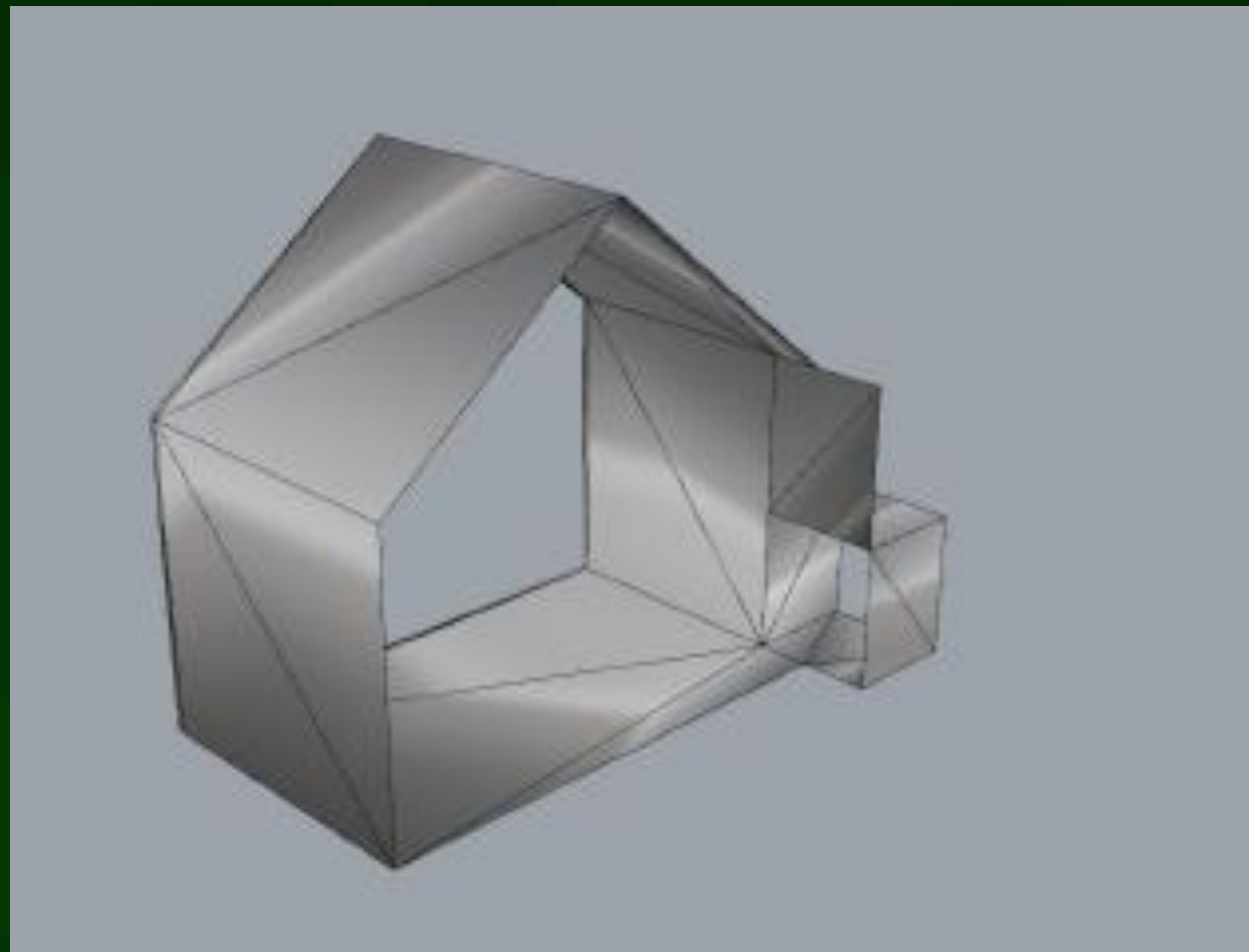
Results



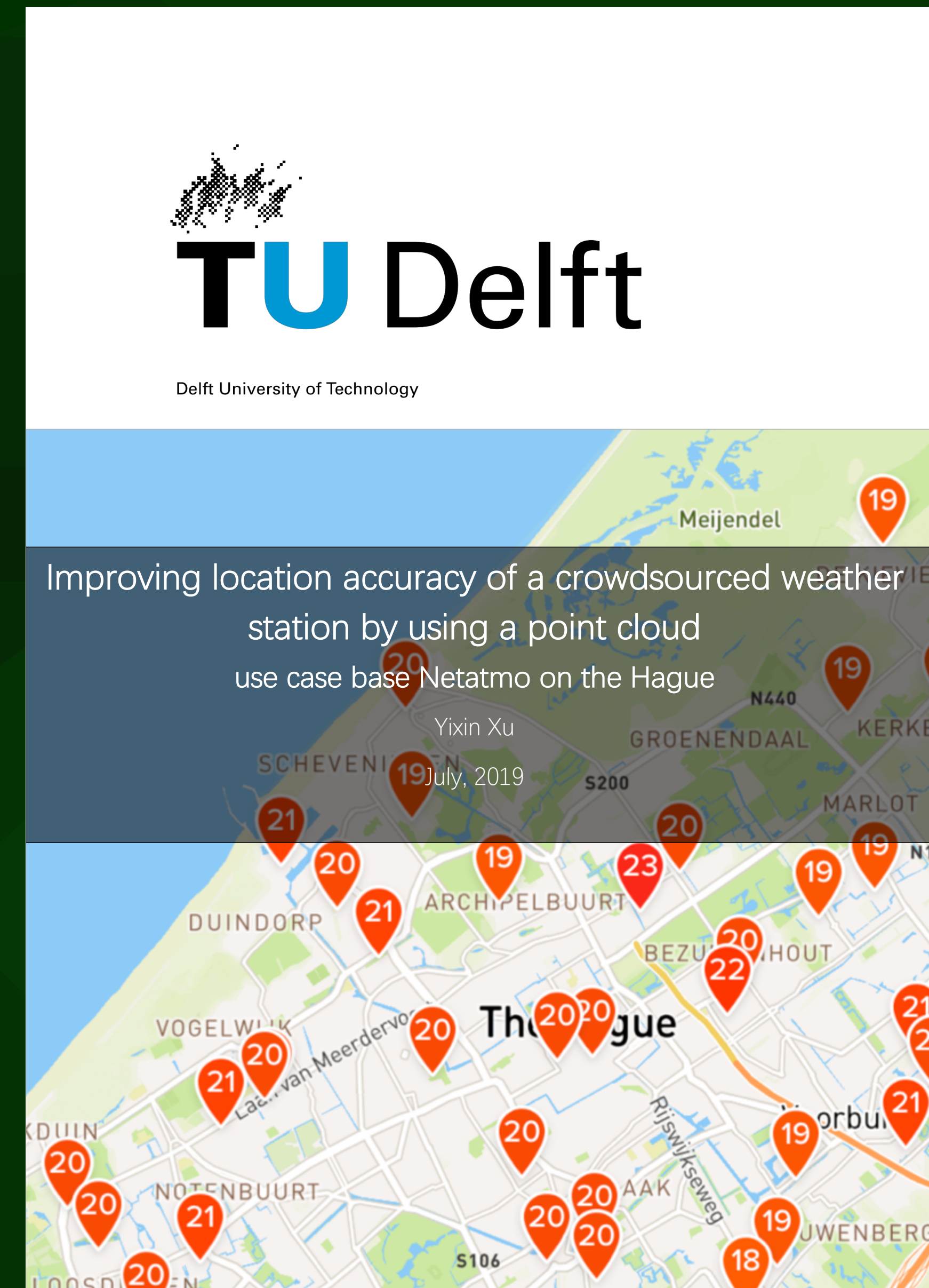
Artefacts



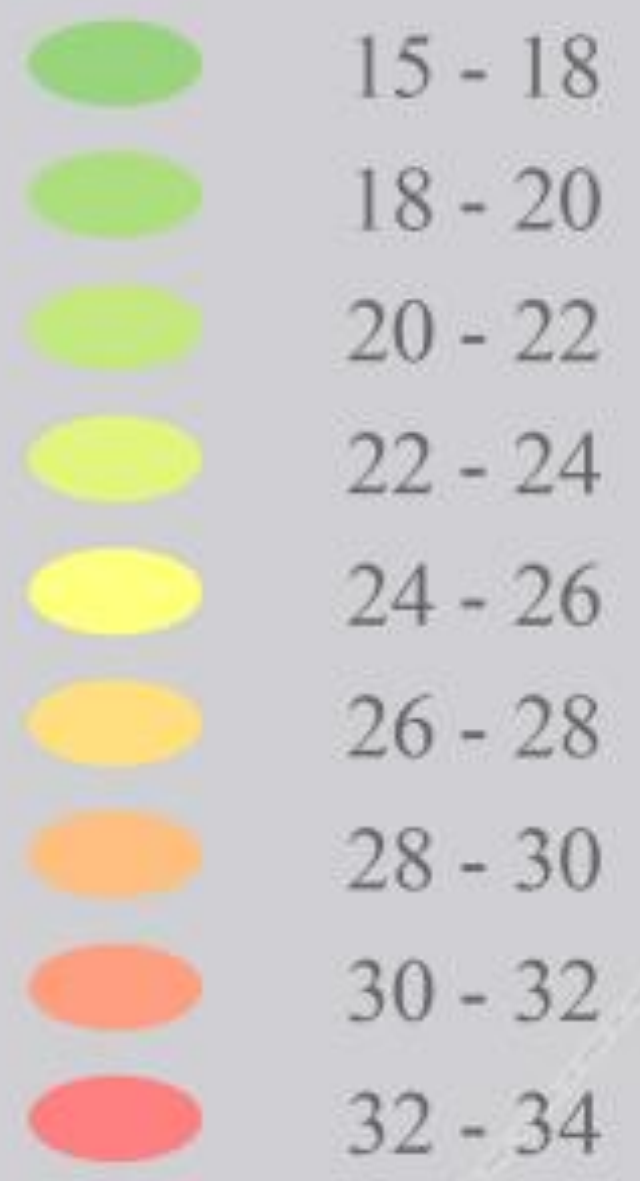
Results



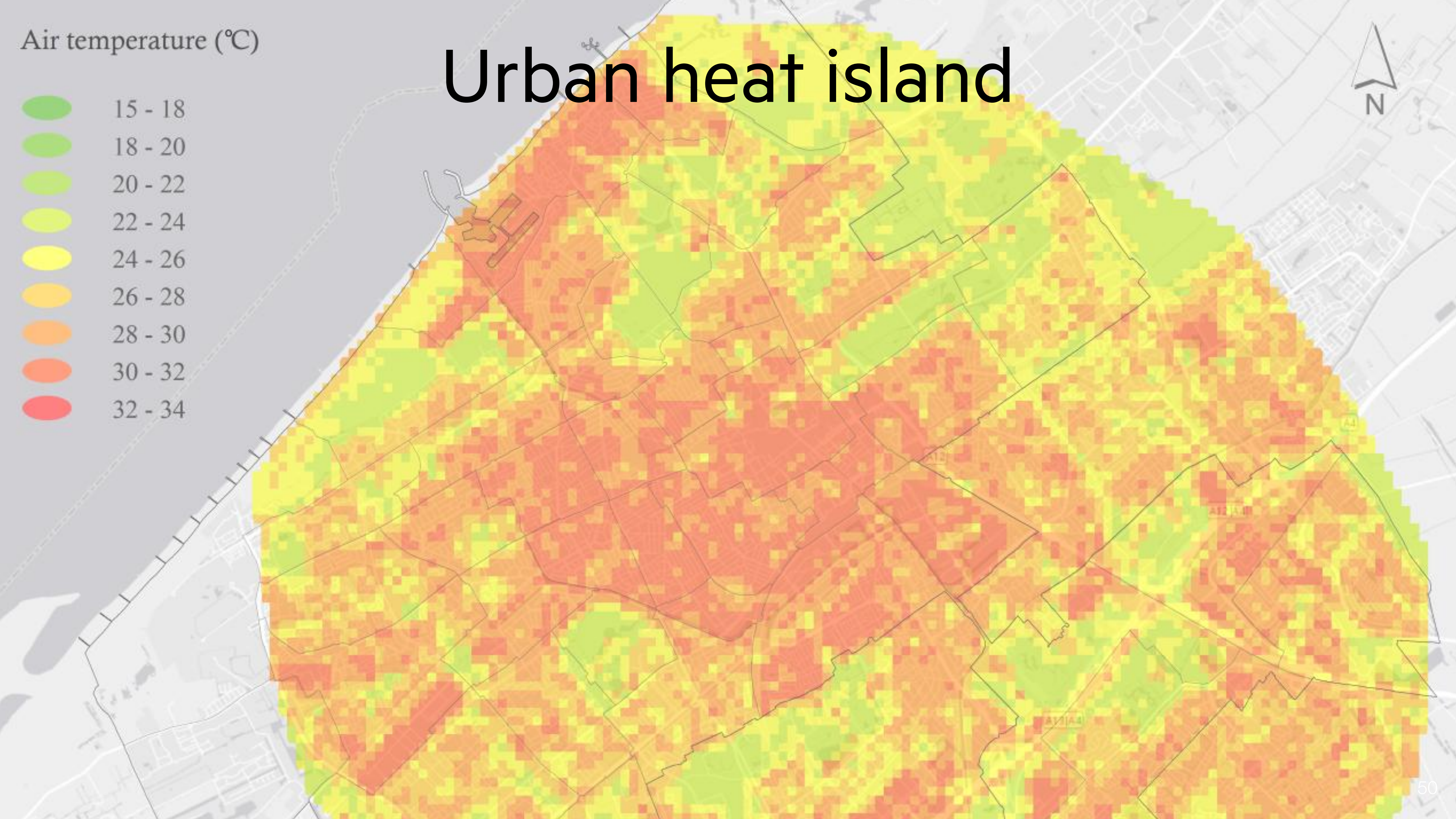
- Motivation: improving the accuracy of the location of personal weather stations for urban heat island research
- Generate potential locations
- Evaluate them through skyview + solar modelling



Air temperature (°C)



Urban heat island



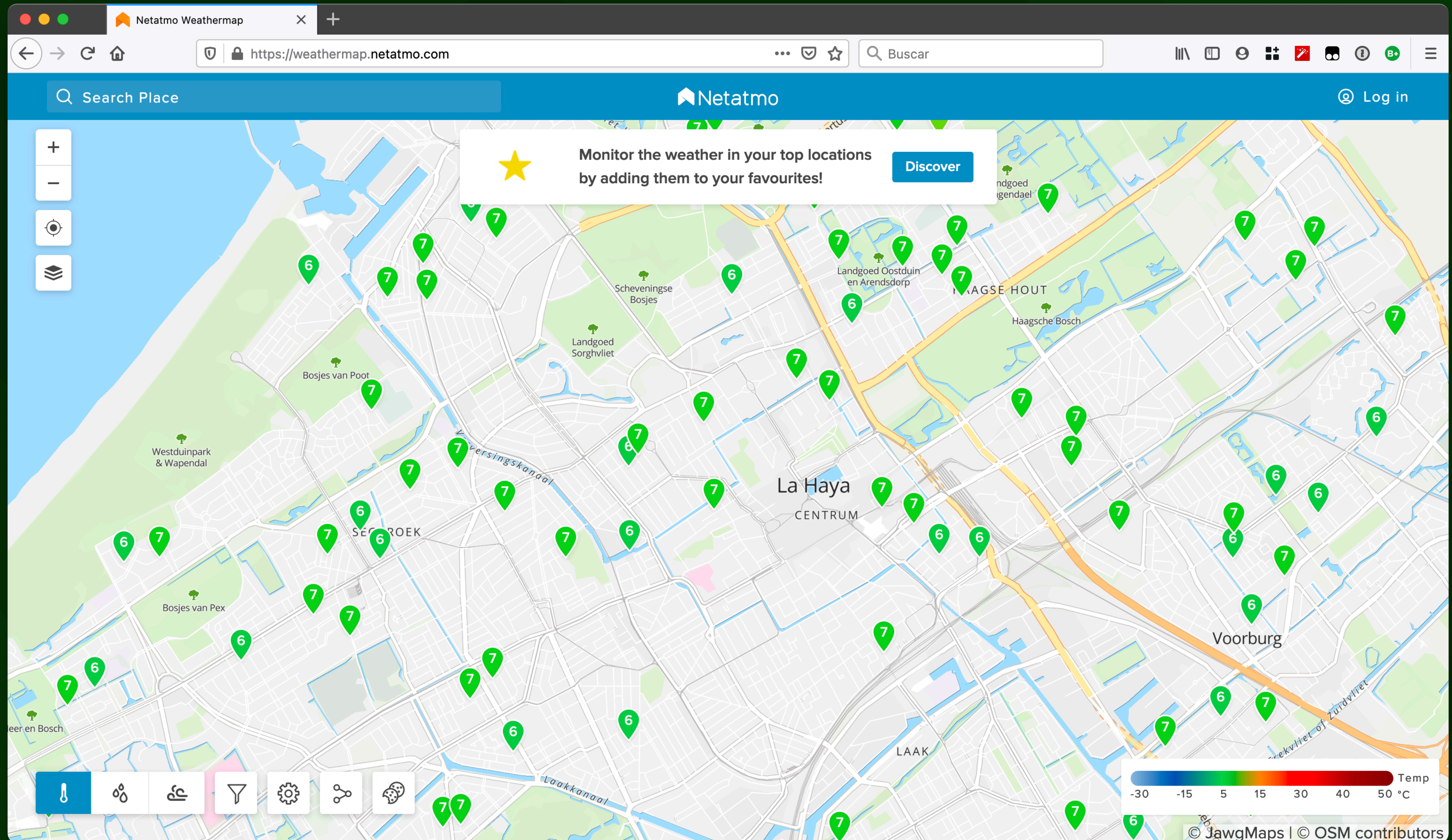
Traditional weather stations



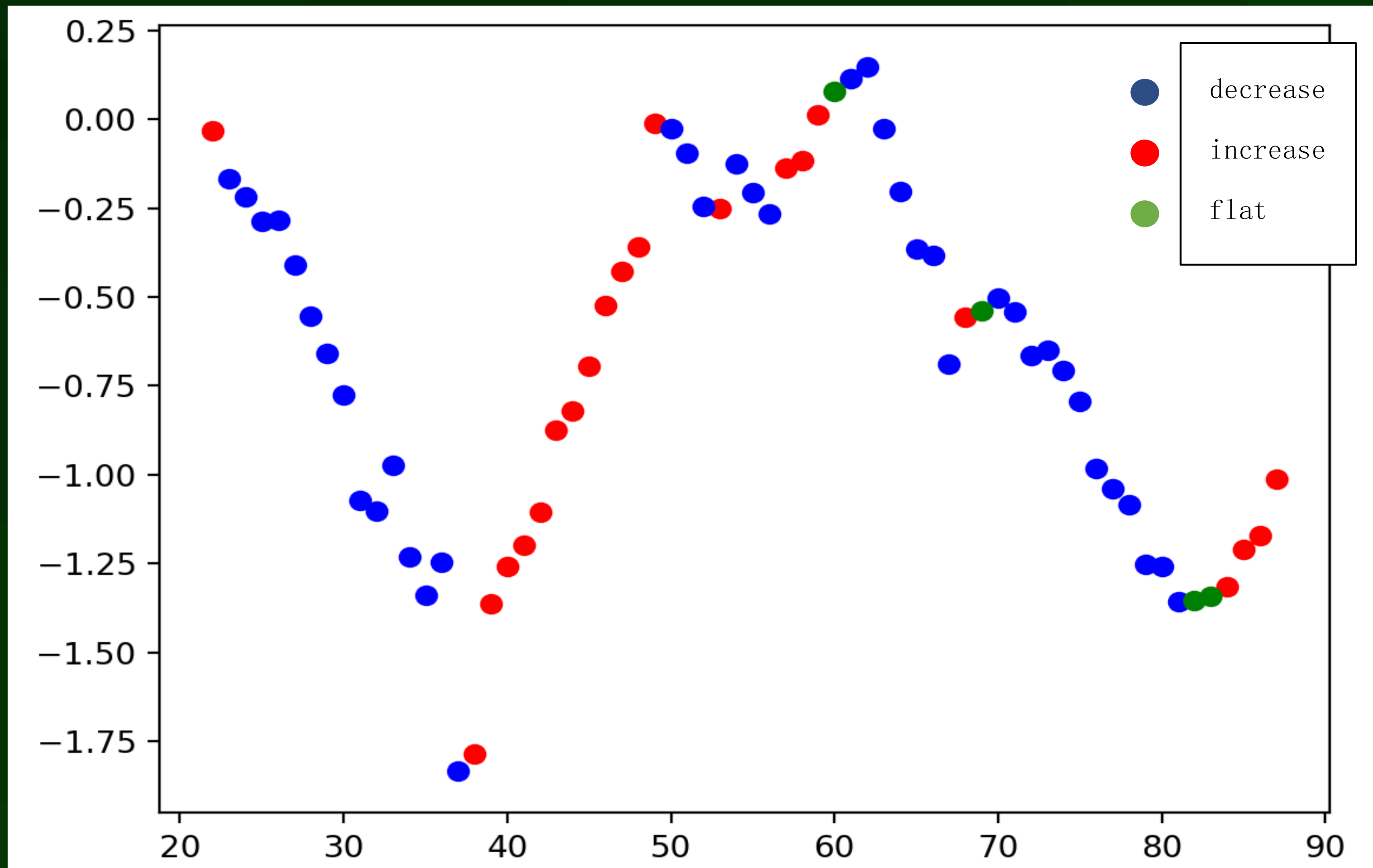
Personal weather stations



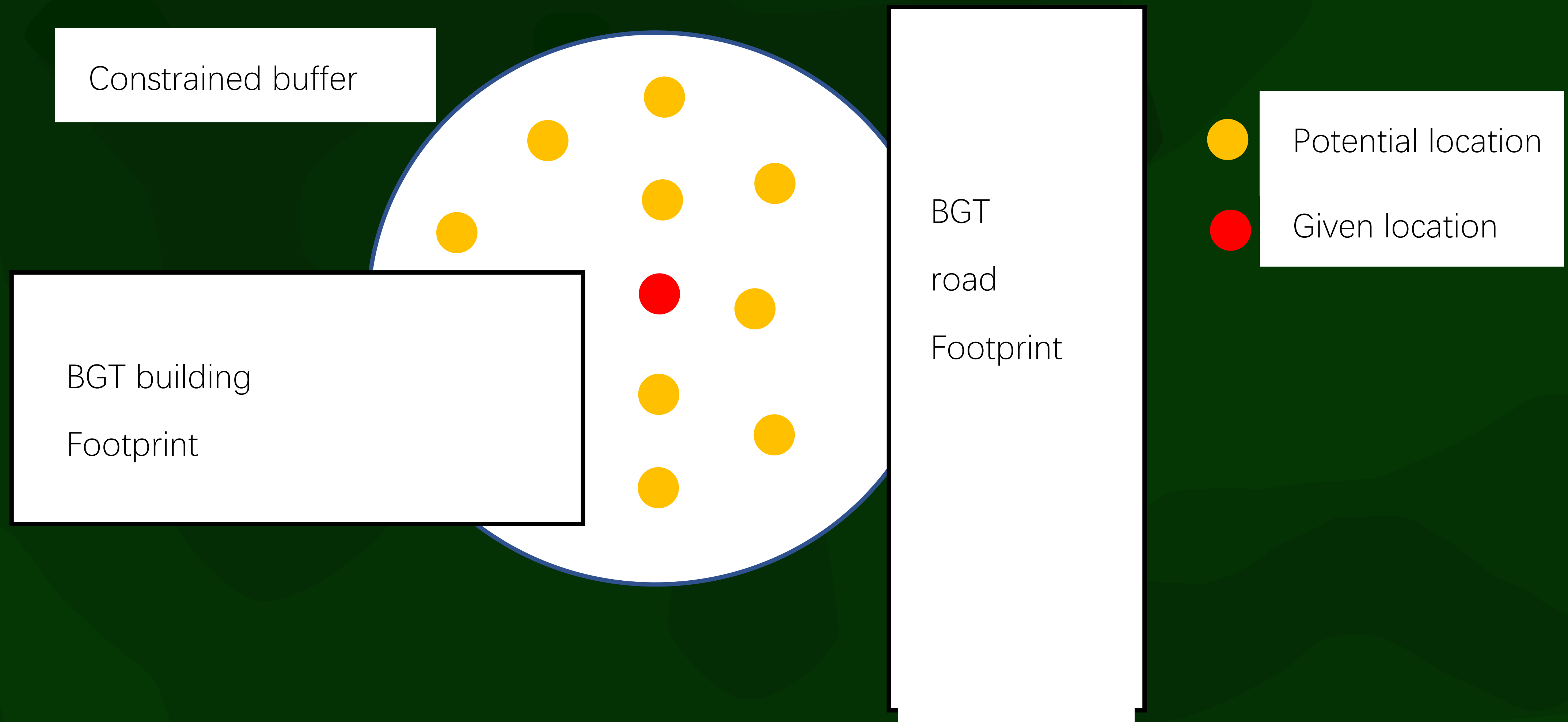
Crowdsourced weather data



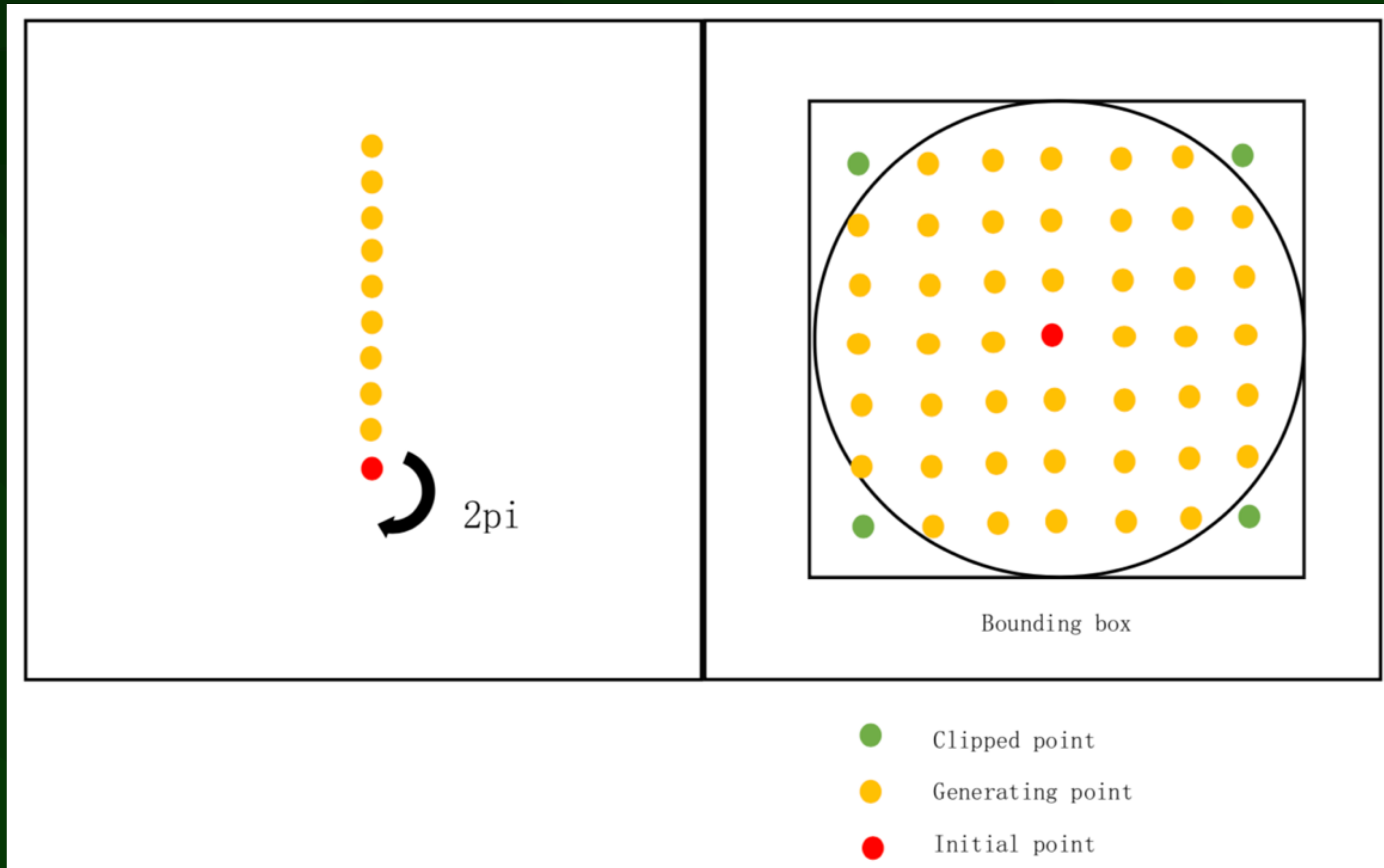
Behaviour



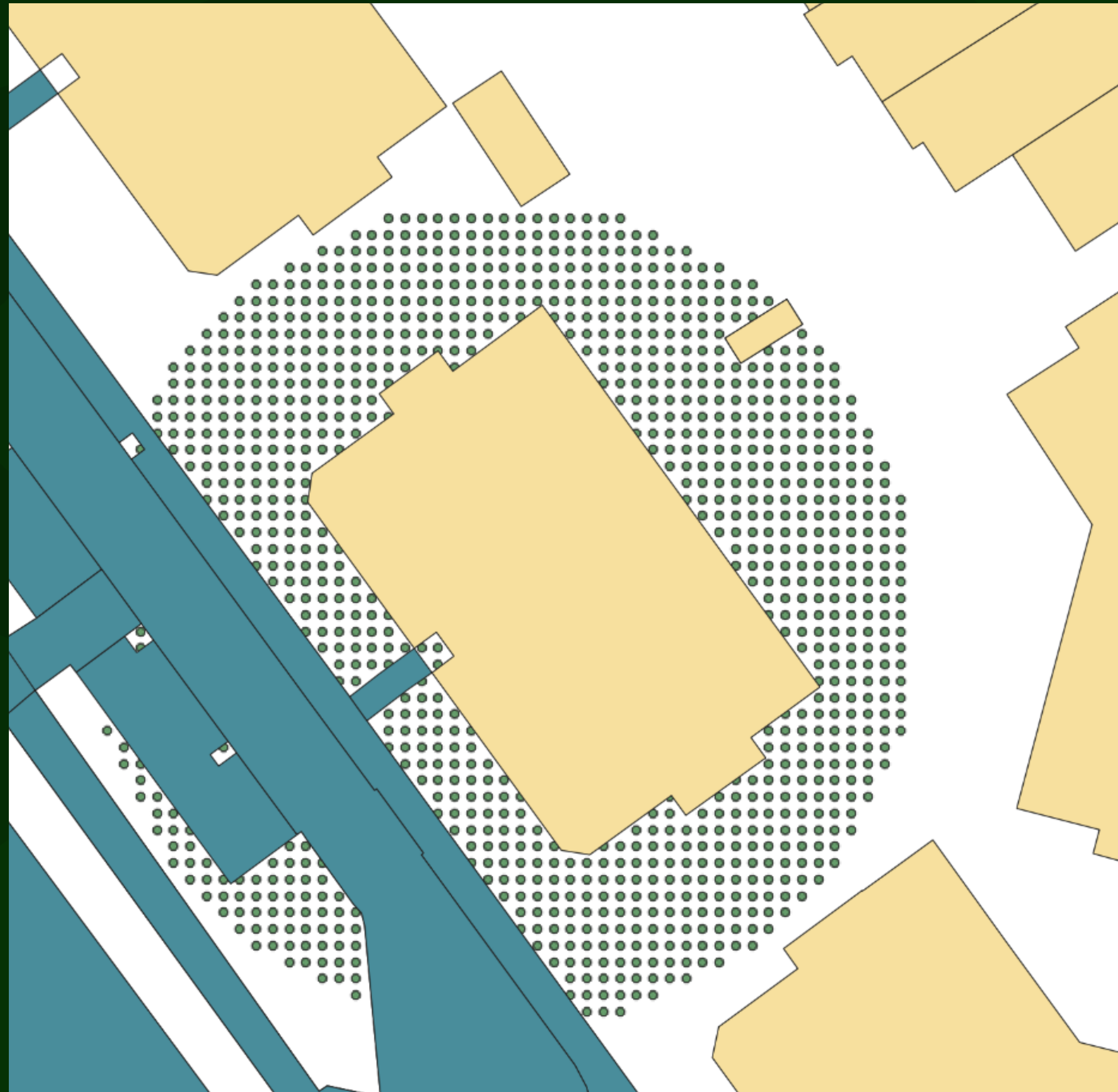
Potential locations



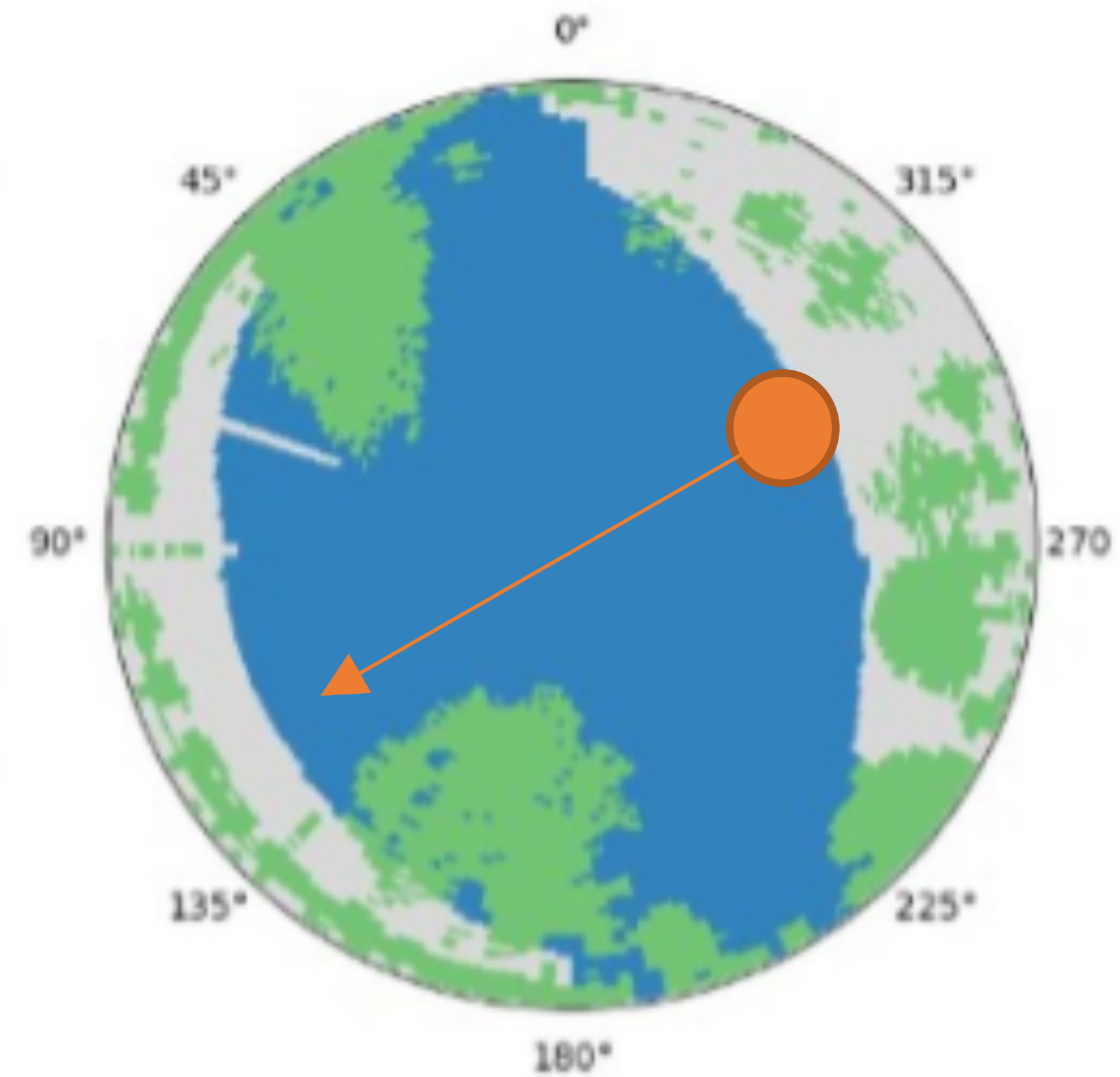
Potential locations



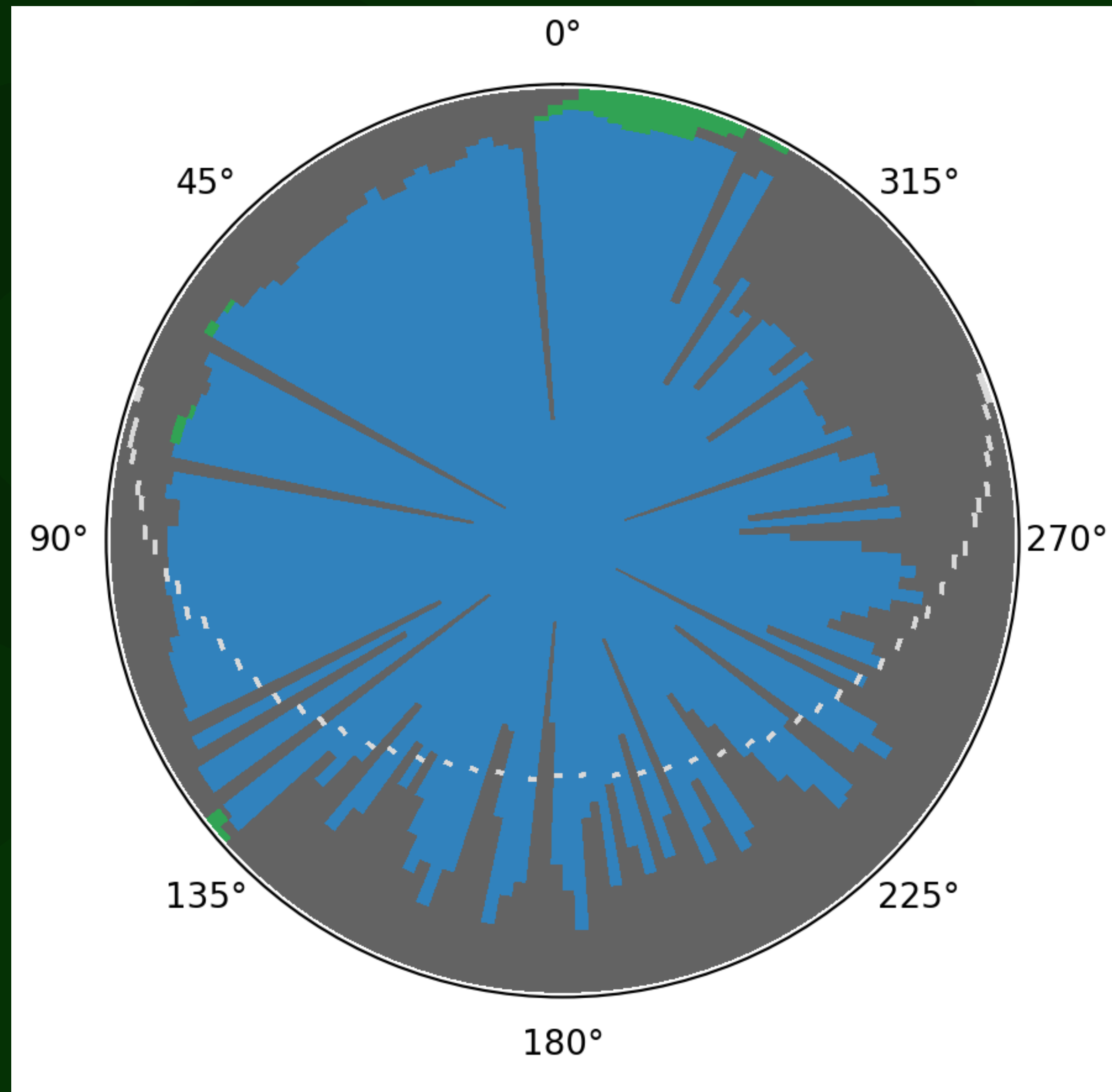
Potential locations



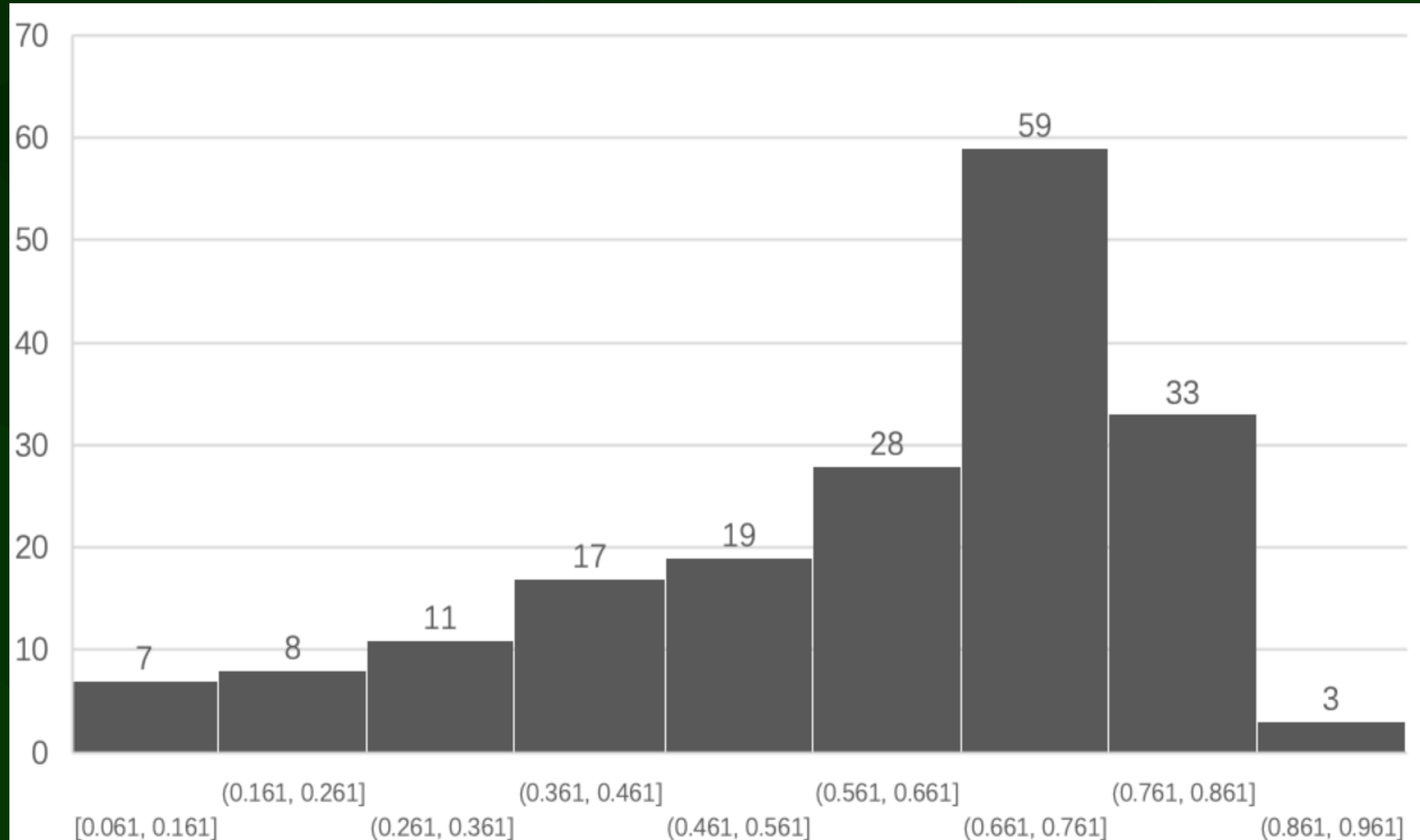
Skyview computation



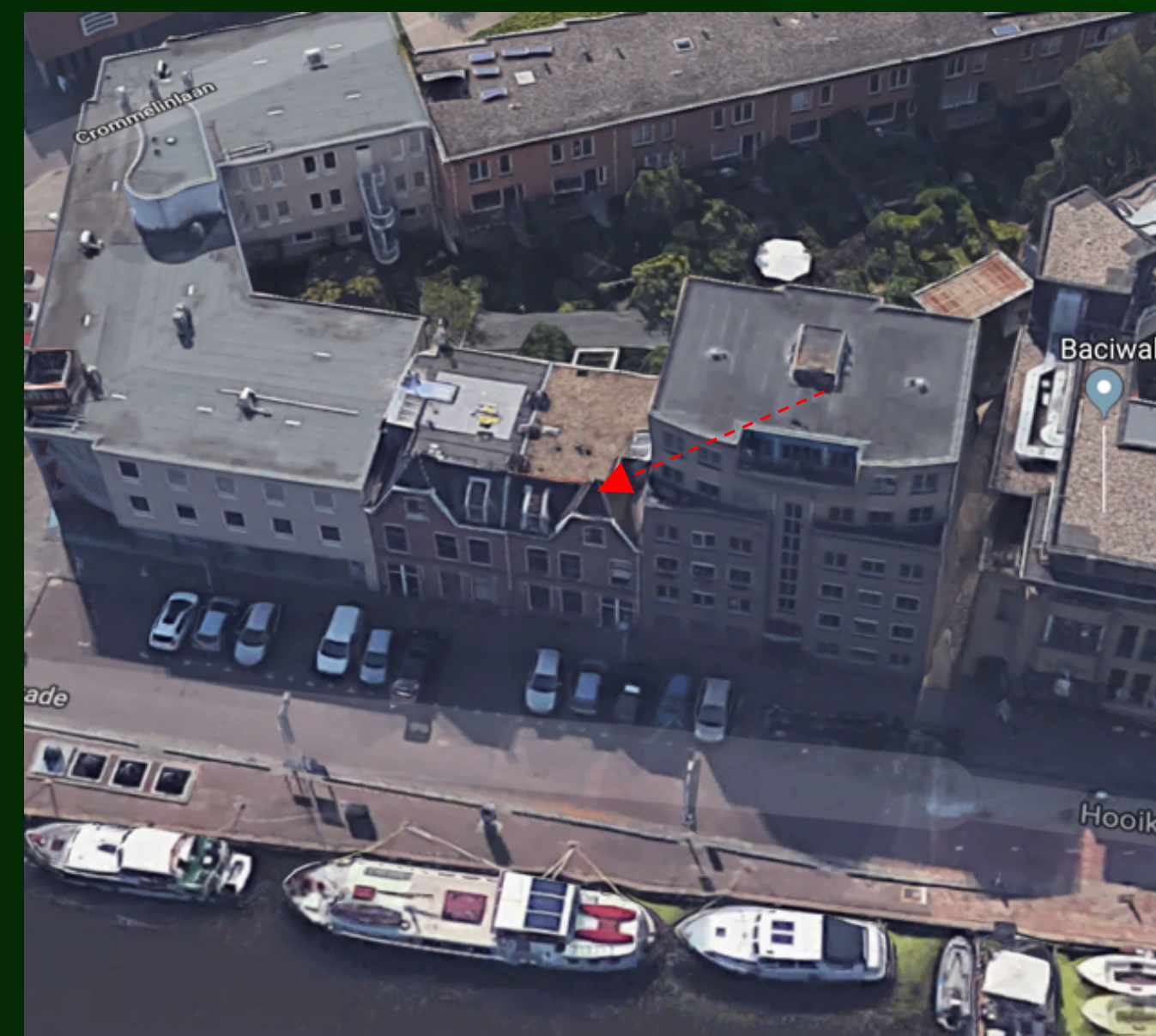
Analysis



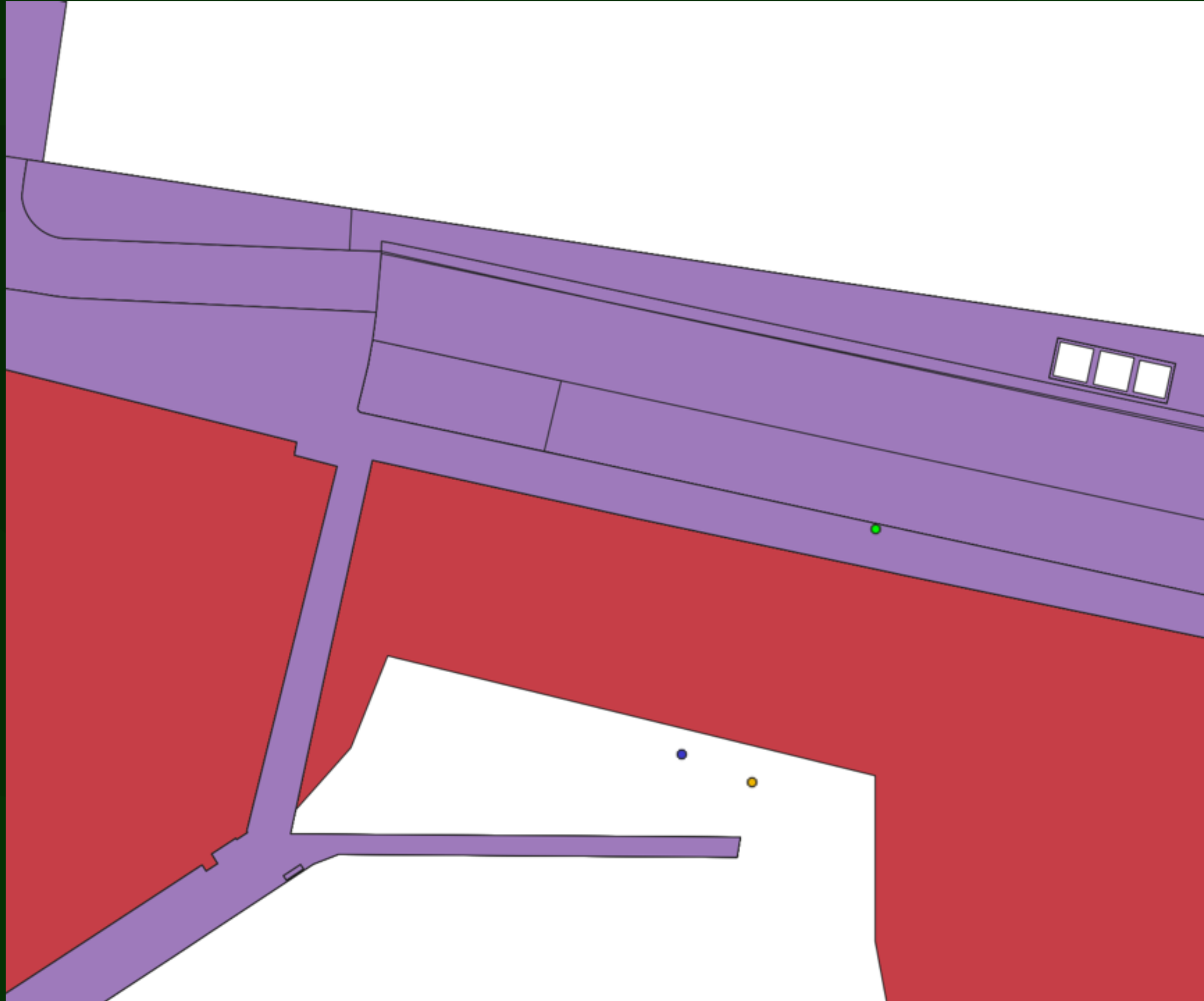
Results



Experiment



Experiment



- Motivation: automate some (simple) building permit checks using a 3DCM
- Formalisation of regulations
- Store necessary data in CityJSON extension
- Automate some checks (car + bicycle parking)

MSc thesis in Geomatics

Automatic building permits checks by means of 3D city models

Jialun Wu
2021



Formalisation of regulations

For residential buildings:

BUH40 = Count BU (function. "home")

AND (A(BU) 40 m2)

BUH40-65 = Count BU (function. "home")

AND (40 A(BU) 65 m2)

BUH65-85 = Count BU (function. "home")

AND (65 A(BU) 85 m2)

BUH85 = Count BU (function. "home")

AND (85 m2 A(BU))

Rules (must be true)

IF BU(function) = "home" THEN

MinNPP = (BUH40*2) + (BUH40-65*3)

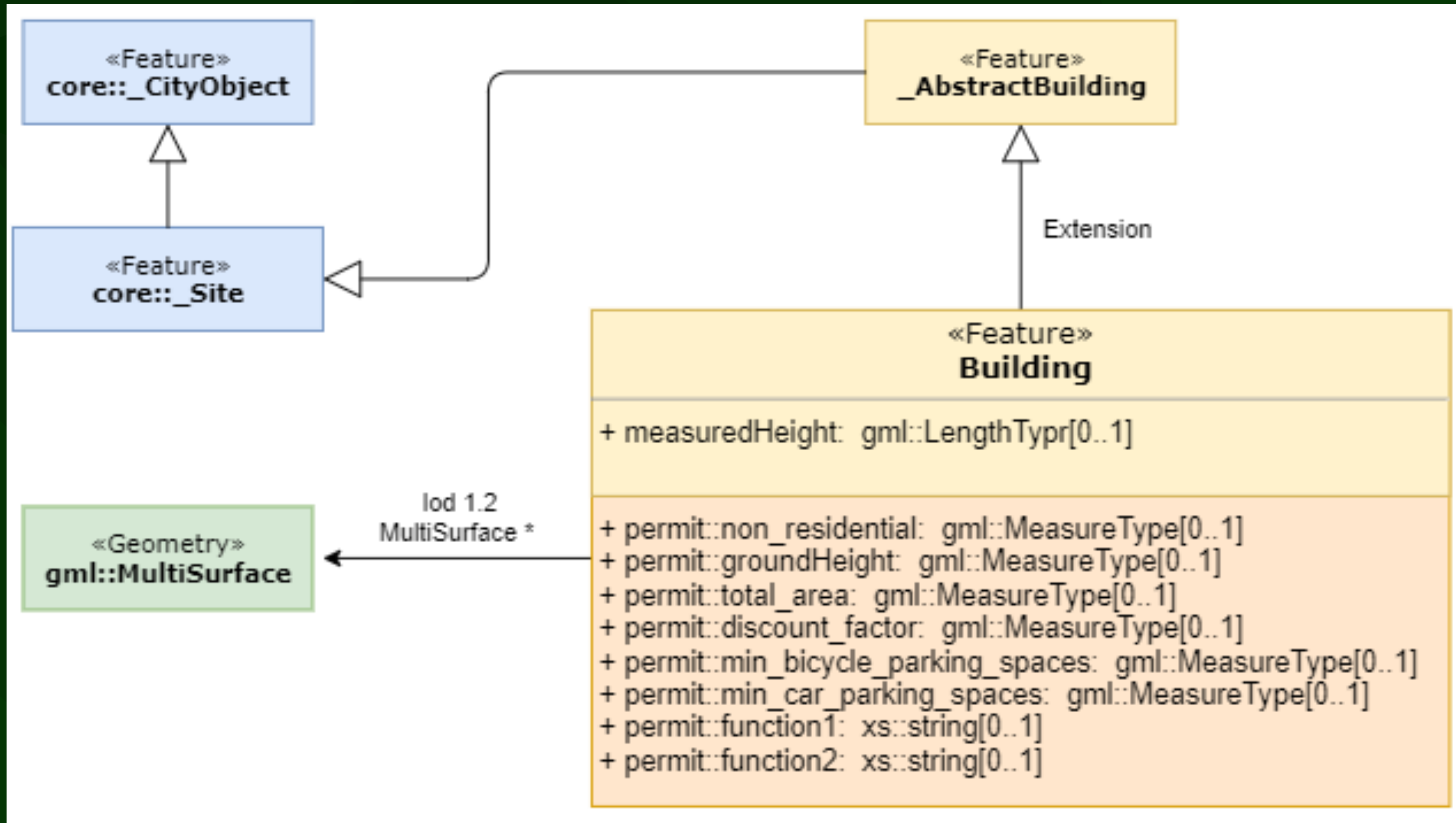
+ (BUH65-85*4) + (BUH85*5)

NewParkings $\geq$ sum(MinNPP) + sum((MinMQPP / parkingArea))

New attributes to store

	Information	Explanation	Sources	name in sources
7*Attributes	id	Bag id of building	BAG	identificatie
	+function	Function of buildings included in codelist	BAG	NR_XXX (different functions)
	+groundHeight	Elevation above sea level at the ground level	3D BAG	ground-0.00
	measuredHeight	Elevation above sea level at rooflevel	3D BAG	roof-0.75
	+zone	Zone where the building is located	Digital map	zone
	+height_valid	Indicate the height is valid	3D BAG	height_valid
	+total_area	Gross floor area (GFA) of building	BAG	Calculation results on different attributs
2*Geometry	type	geometry type of buildings	BAG	type
	coordinates	a lists contain [x,y,z] 3D coordinates	BAG	coordinates

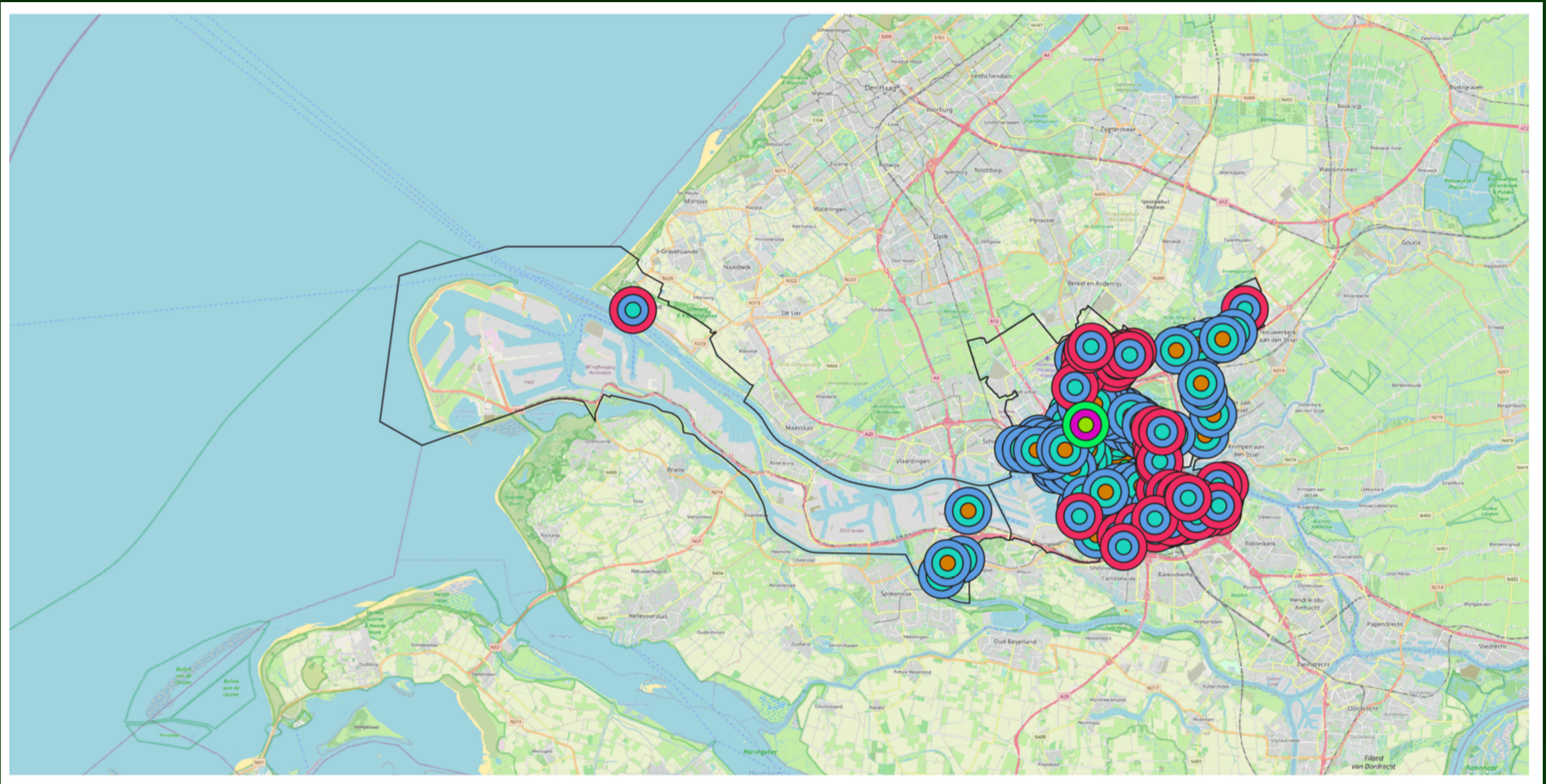
CityJSON extension



CityJSON extension

```
"68": {  
  "type": "Building",  
  "toplevel": true,  
  "attributes": {  
    "+height_valid": 1,  
    "+non_residential": 1,  
    "+groundHeight": 0,  
    "measuredHeight": 28.0,  
    "+total_area": 1371.56879999999998,  
    "+discount_factor": 0.95,  
    "+min_bicycle_parking_spaces": 117,  
    "+min_car_parking_spaces": 78,  
    "+function": "catering I"
```

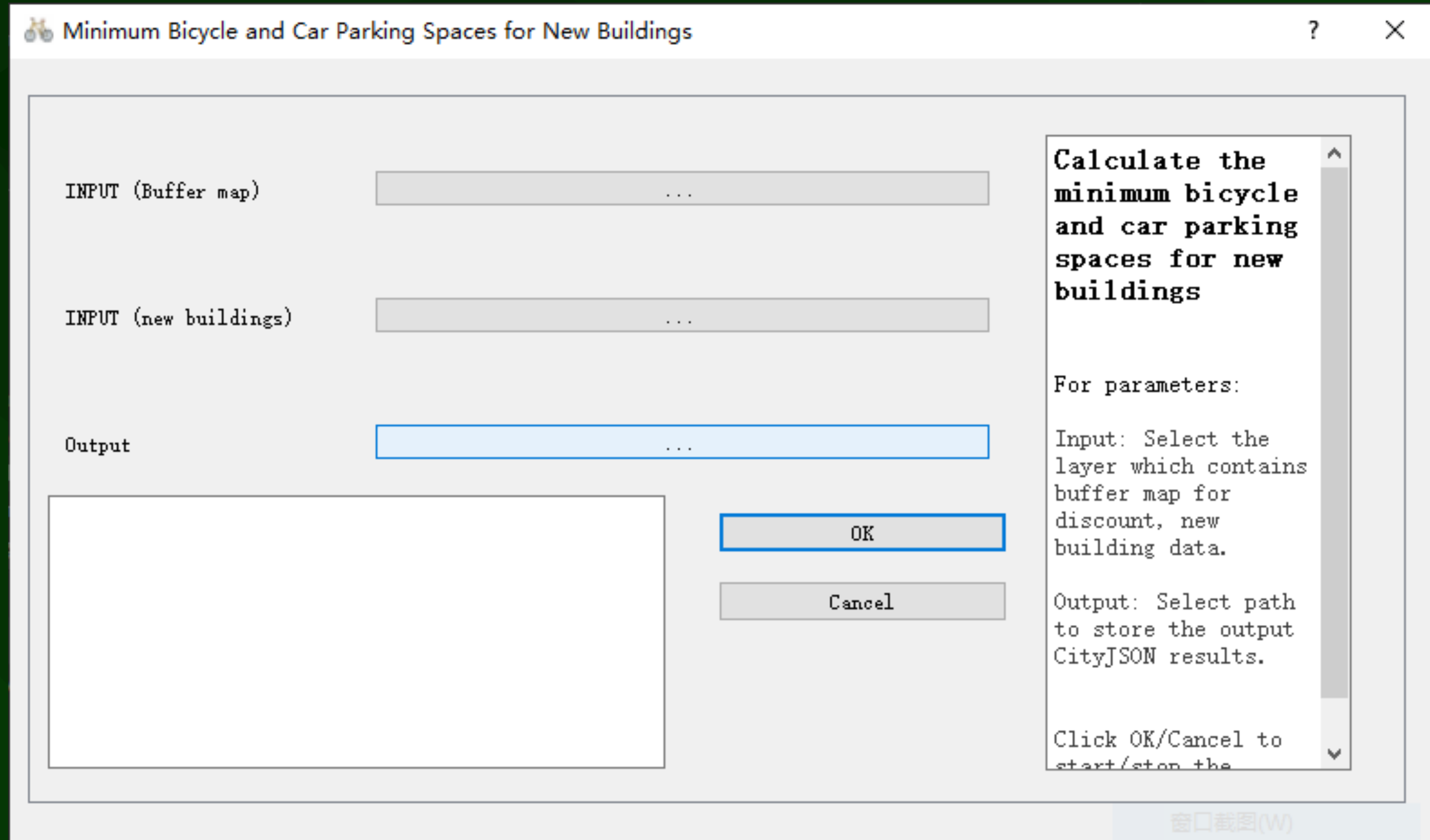

Generating required info



Programming checks

```
N_40 = int(f['properties']['N_40'])
N_40_65 = int(f['properties']['N_40_65'])
N_65_85 = int(f['properties']['N_65_85'])
N_85_120 = int(f['properties']['N_85_120'])
N_120 = int(f['properties']['N_120'])
if f['properties']['zone'] == 'A':
    oneb['attributes']['+min_car_parking_spaces'] = int(
        N_40 * 0.1 + N_40_65 * 0.4 + N_65_85 * 0.6 + N_85_120 * 1 +
        N_120 * 1.2)
if f['properties']['zone'] == 'B':
    oneb['attributes']['+min_car_parking_spaces'] = int(
        N_40 * 0.1 + N_40_65 * 0.5 + N_65_85 * 0.8 + N_85_120 * 1 +
        N_120 * 1.2)
if f['properties']['zone'] == 'C':
    oneb['attributes']['+min_car_parking_spaces'] = int(
        N_40 * 0.1 + N_40_65 * 0.6 + N_65_85 * 1.4 + N_85_120 * 1.6
        + N_120 * 1.8)
```


Results: tool

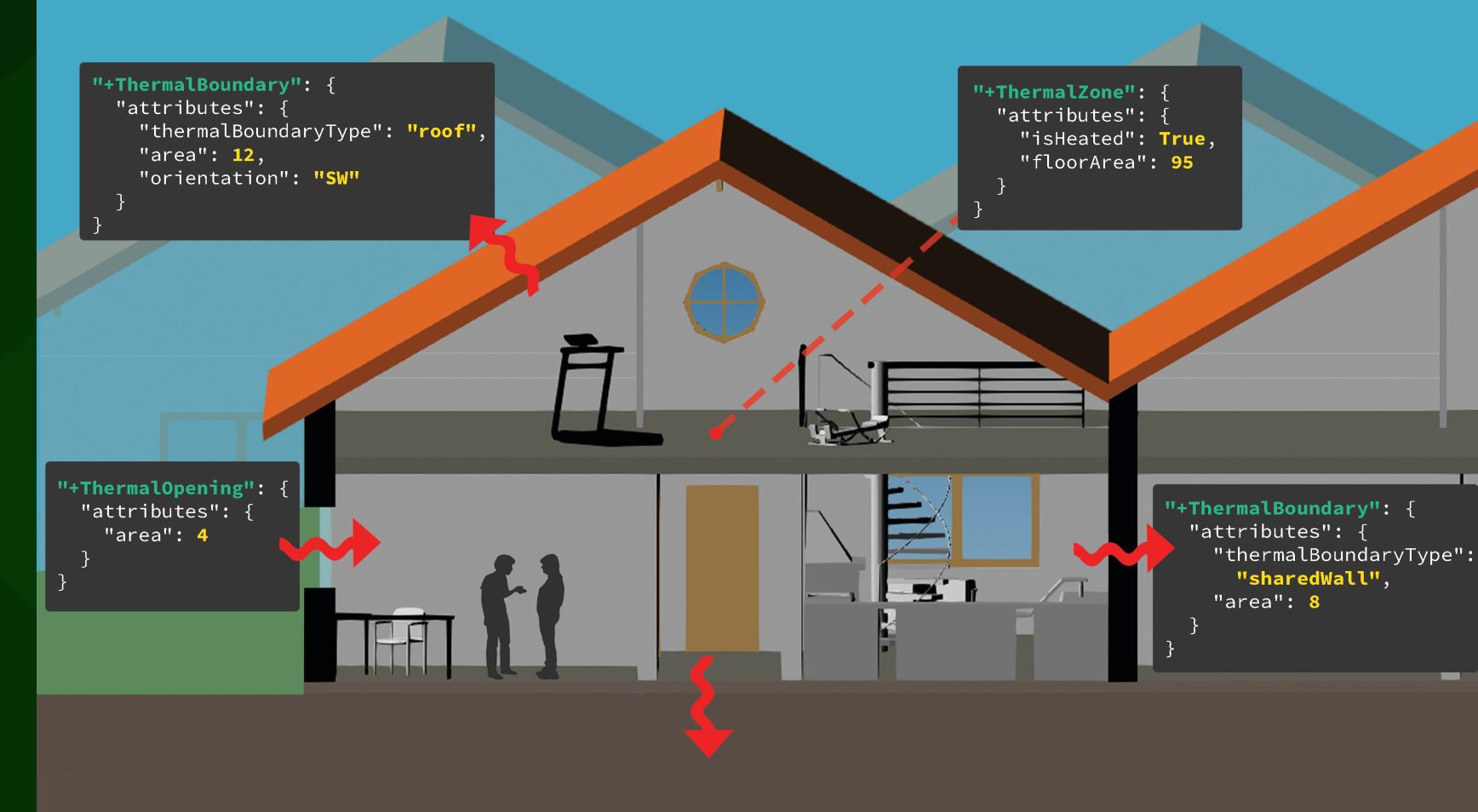


- Motivation: use 3DCM for space heating demand calculations
- Develop CityJSON extension with all required information
- Implement space heating models
- Use implementation to improve extension design

MSc thesis in Geomatics

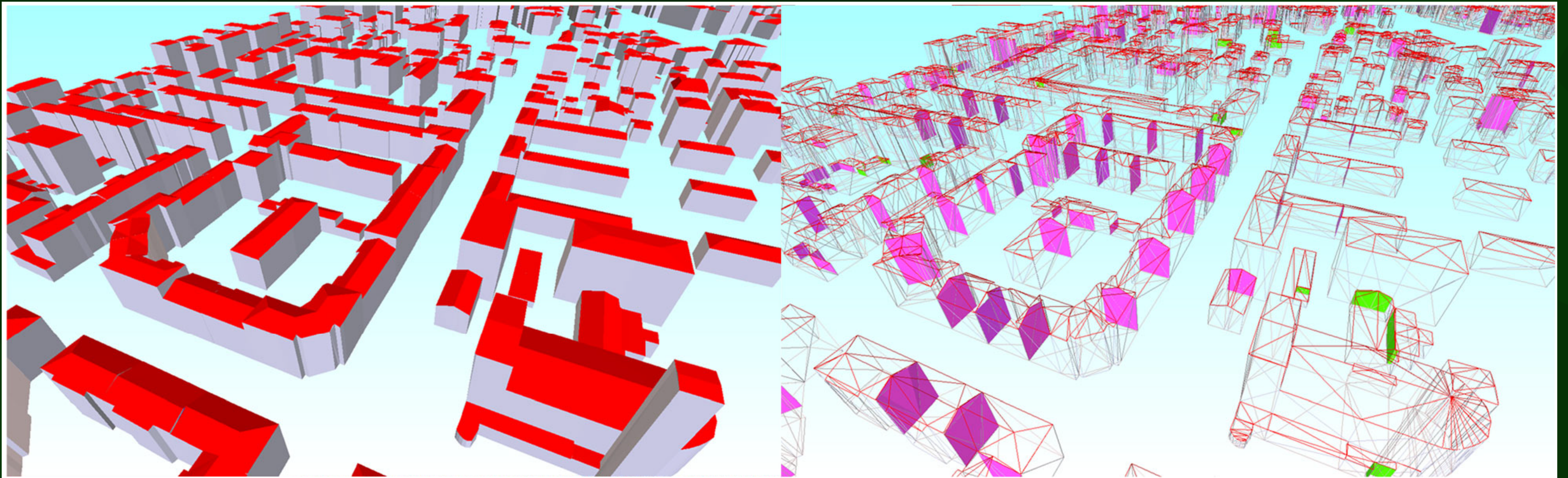
Development and Testing of the CityJSON Energy Extension for Space Heating Demand Calculation

Özge Tufan | 2022





Storing new (complex) geometries



New attributes

Net internal area	Excludes internal structural elements
Class	Type of use of the building, e.g. residential, mixed-use
Function*	Further description of the class, e.g., health, business
Usage	Whether the building is still in use
Measured height	Height of the building, in m
Relative to terrain	Whether the building is (entirely) above or below the terrain
Roof type	E.g. slanted, single/multiple horizontal
Year of construction	Construction year of the building
Footprint area*	Footprint area, calculated from the LoD0 geometry, in m^2
Storeys above ground*	Number of storeys situated above ground level
Storeys below ground*	Number of storeys situated below ground level
Building name*	Unique name of the building
Is single part	Boolean value to show whether the building has <i>BuildingParts</i>
# of adjacent buildings	Number of topologically adjacent buildings
LoD2 volume*	Building volume, calculated from the LoD2 geometry, in m^3
LoD max	Maximum LoD present for the building
Building (pand) ID	Unique ID of the building
List adjacent buildings	Building (pand) ID of topologically adjacent buildings
Surface ID	Unique ID of the <i>BoundarySurface</i>
Parent building ID	Building (pand) ID of the building that the surface belongs to
Surface name	Unique name of the <i>BoundarySurface</i>
Azimuth	Azimuth of the surface, in <i>degrees</i>
Inclination	Inclination of the surface, in <i>degrees</i>
Direction	Direction of the surface
LoD2 area	Surface area, calculated from the LoD2 geometry, in m^2
Surface normal	Normal vector of the surface

New attributes

```
"extraAttributes": {  
  "Building": {  
    "+buildingType": {...},  
    "+constructionWeight": {...},  
    "+volume": {...},  
    "+floorArea": {...},  
    "+heightAboveGround": {...}  
  }  
}
```

```
"Build1": {  
  "type": "Building",  
  "geometry": [...],  
  "attributes": {  
    "+buildingType": "singleFamily",  
    "+constructionWeight": "heavy",  
  }  
}
```


New City Objects

```
"extraCityObjects": {
  "+WeatherData": {
    "type": "object",
    "properties": {
      "type": {...},
      "attributes": {
        "type": "object",
        "properties": {
          "weatherDataType": {...},
          "values": {...},
          "position": {...}
        }
      }
    }
  }
  ...
}
```

```
"OutdoorTemperature": {
  "type": "+WeatherData",
  "attributes": {
    "weatherDataType": "airTemperature",
    "values": "RegularTimeSeries1",
    //ID of TimeSeries object
  }
},
"RegularTimeSeries1": {
  "type": "+RegularTimeSeries",
  "attributes": {
    "values": [2.61, 4.82, 5.91, 9.32,
              14.73, 16.12],
    ...
  }
}
```

Test data



Results: heating energy demand



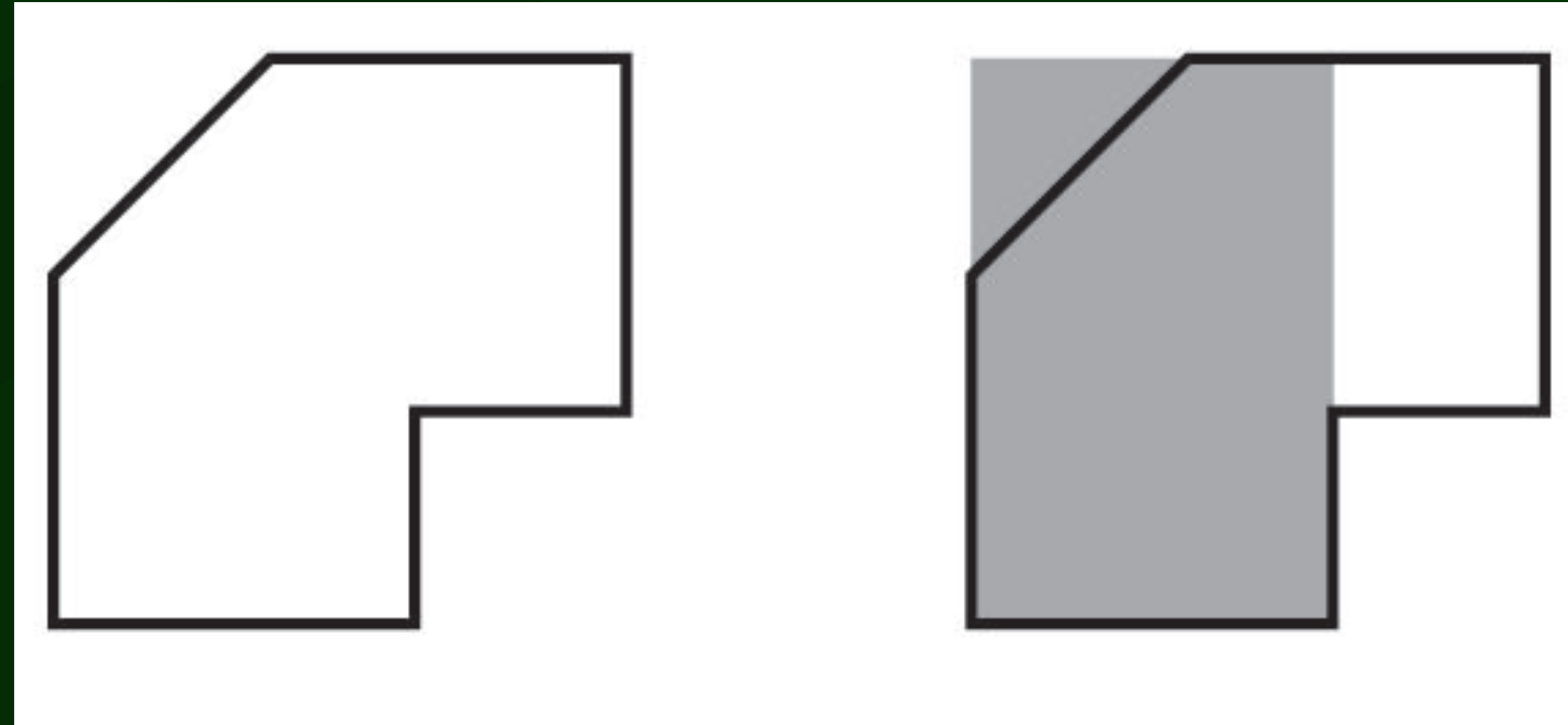
- Motivation: unreliable or non-existent information in IFC models
- Automatically create shapes of rooms, storeys and apartments
- Built on IfcOpenShell

MSc thesis in Geomatics

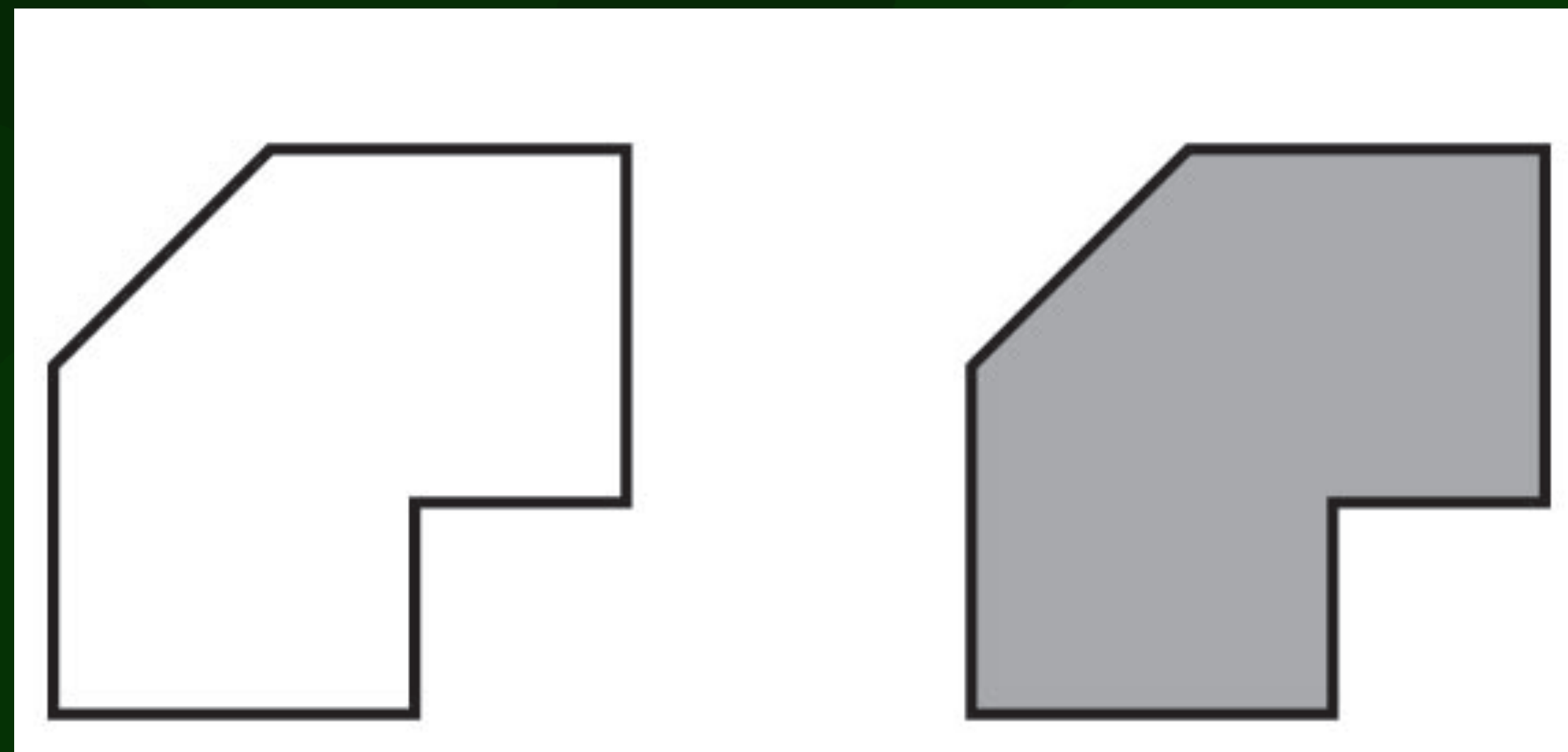
Automatic building feature
detection and reconstruction
in IFC models

Jasper van der Vaart
2022

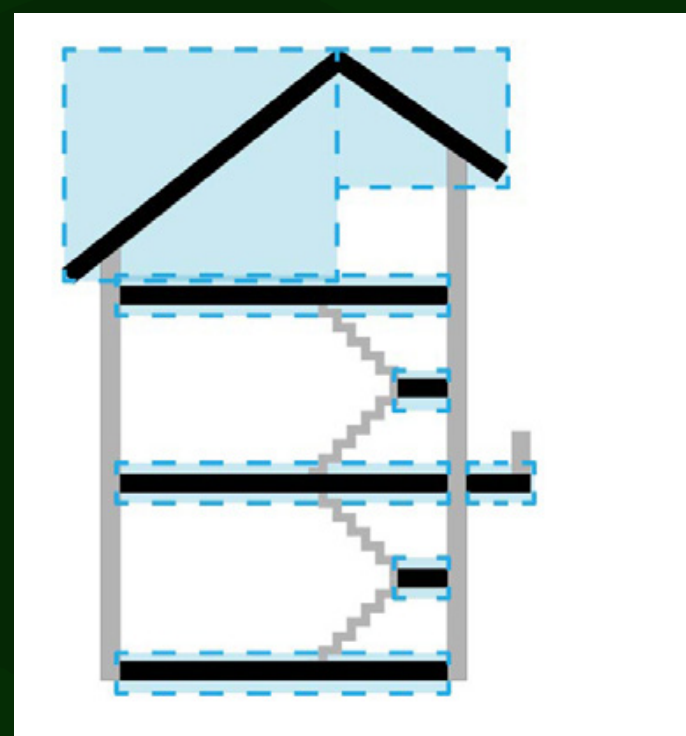
Current IfcSpaces



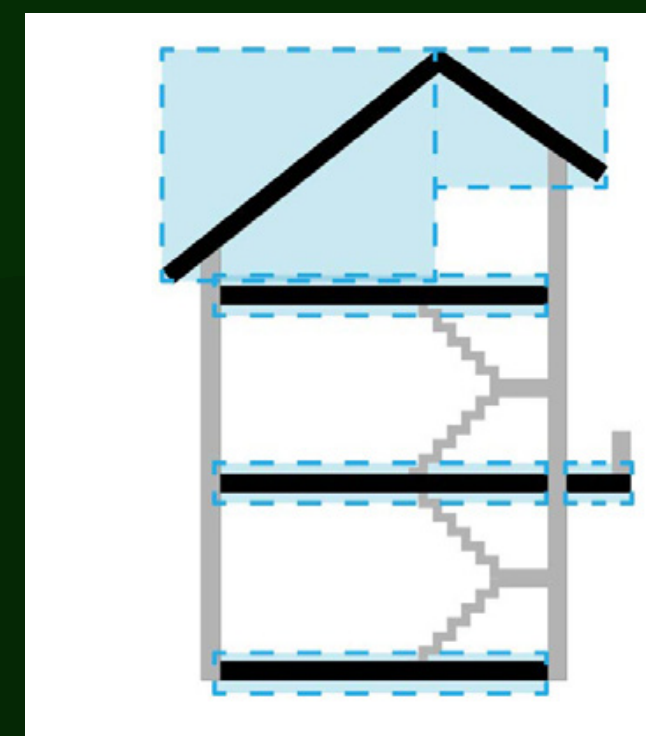
(a)



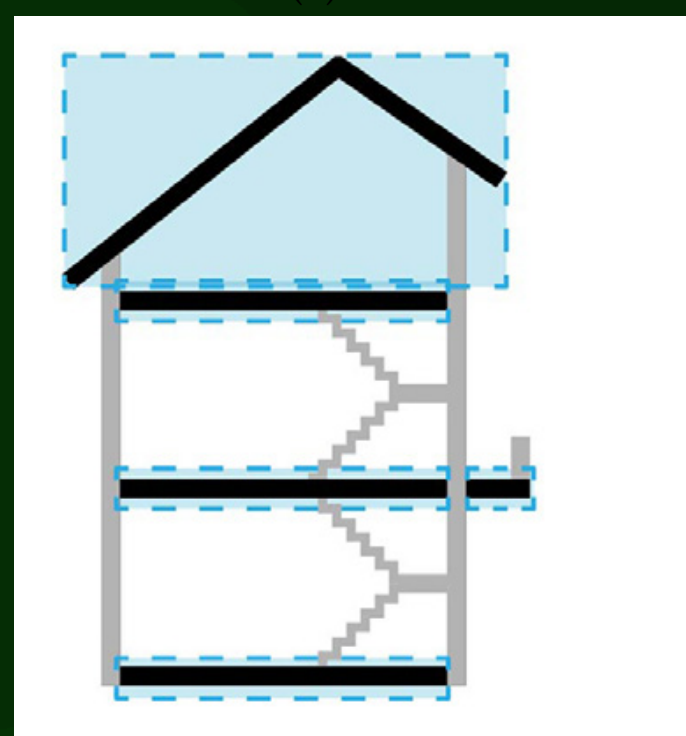
Computing storeys



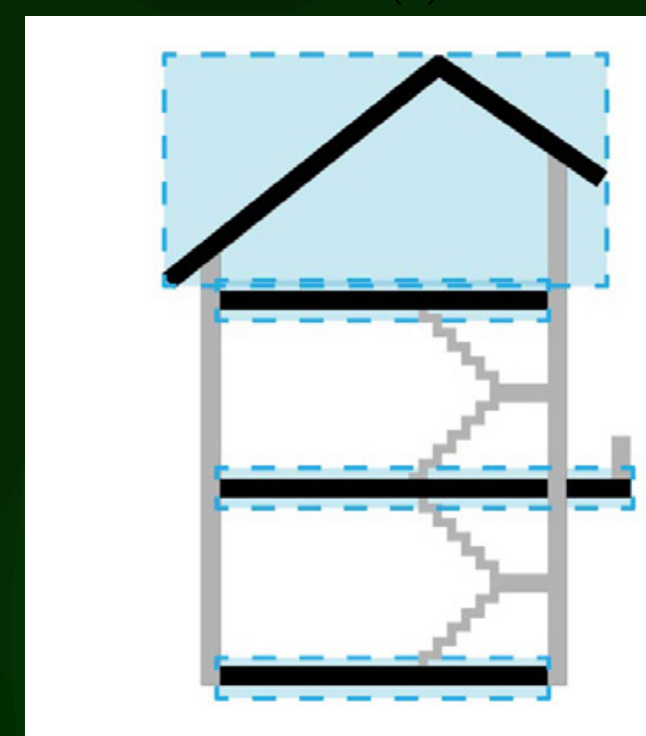
(a)



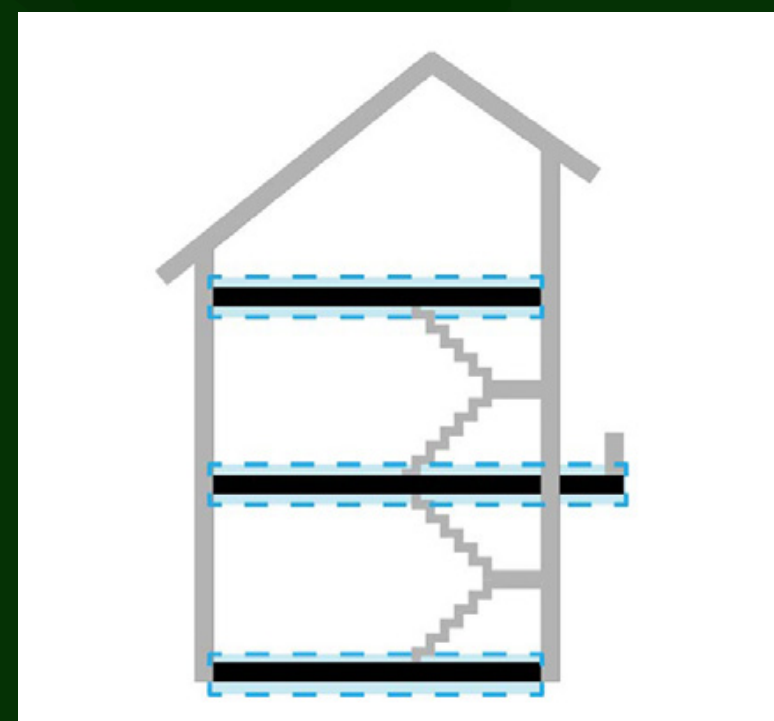
(b)



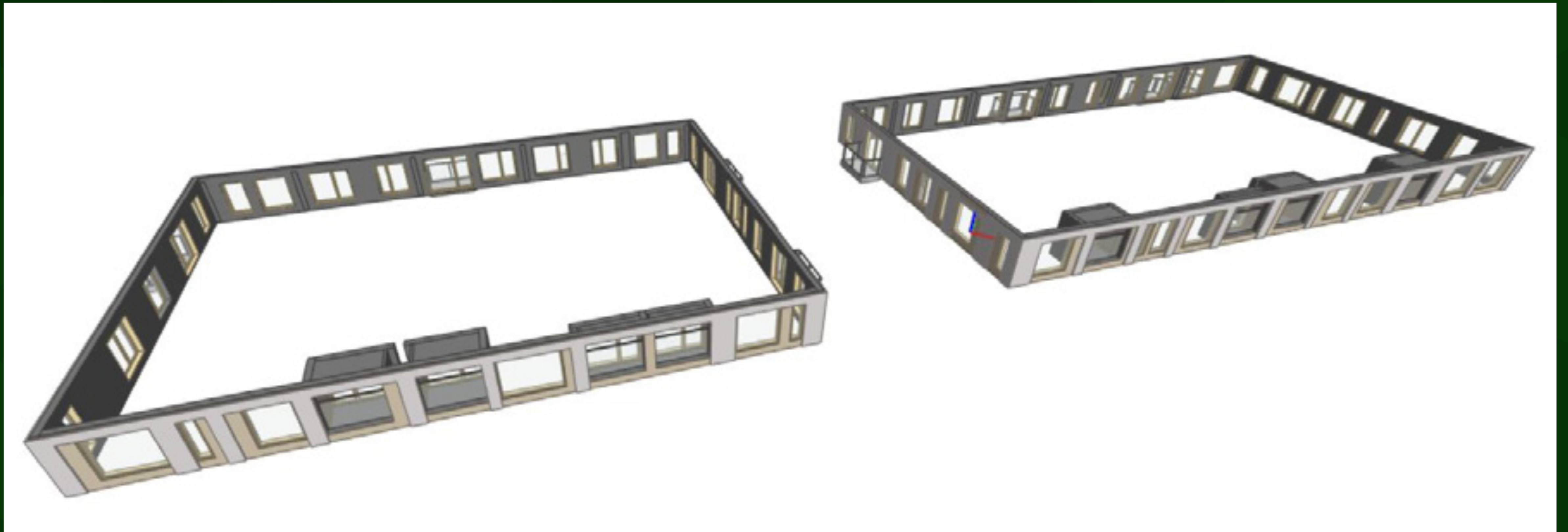
(c)



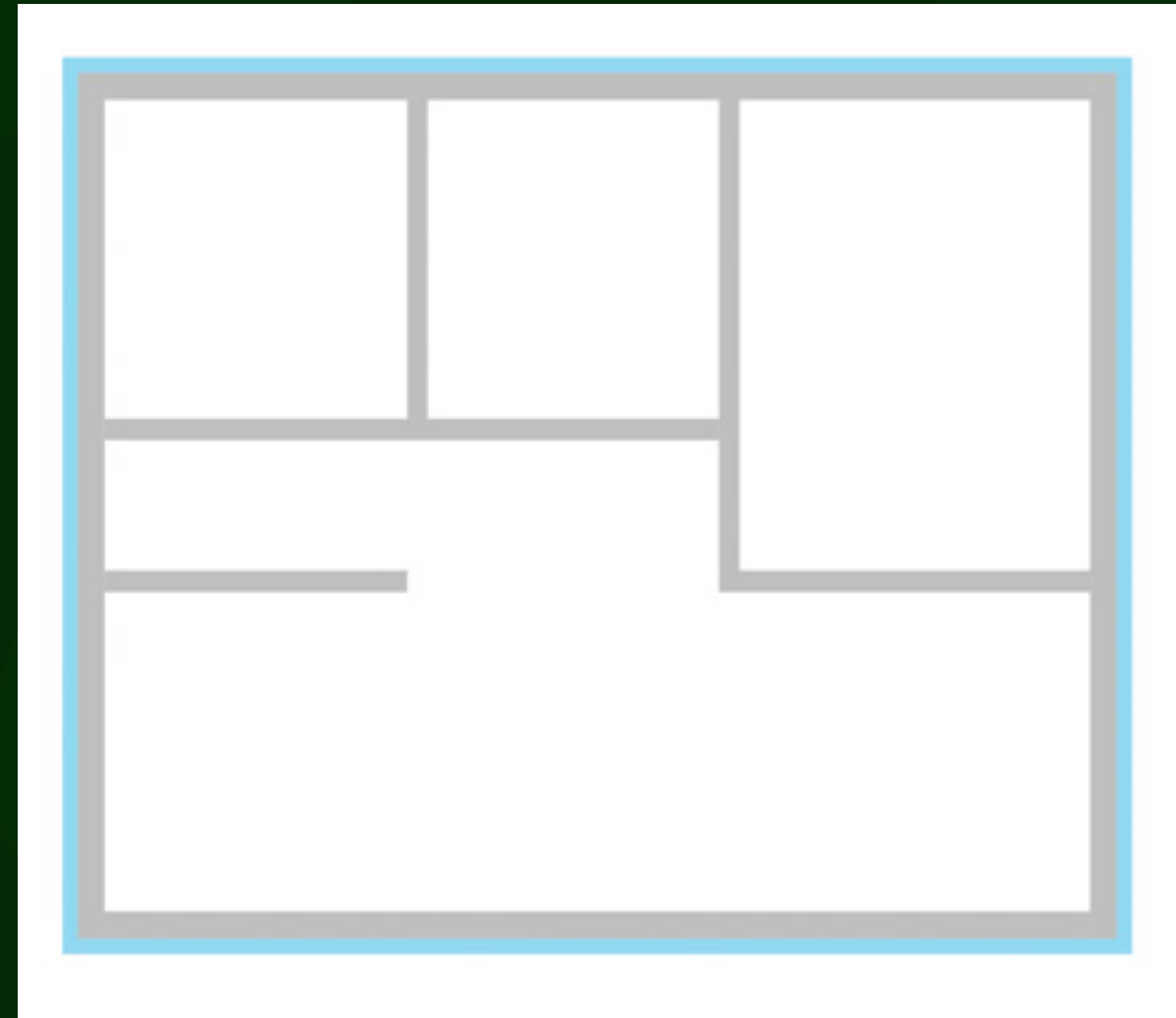
(d)



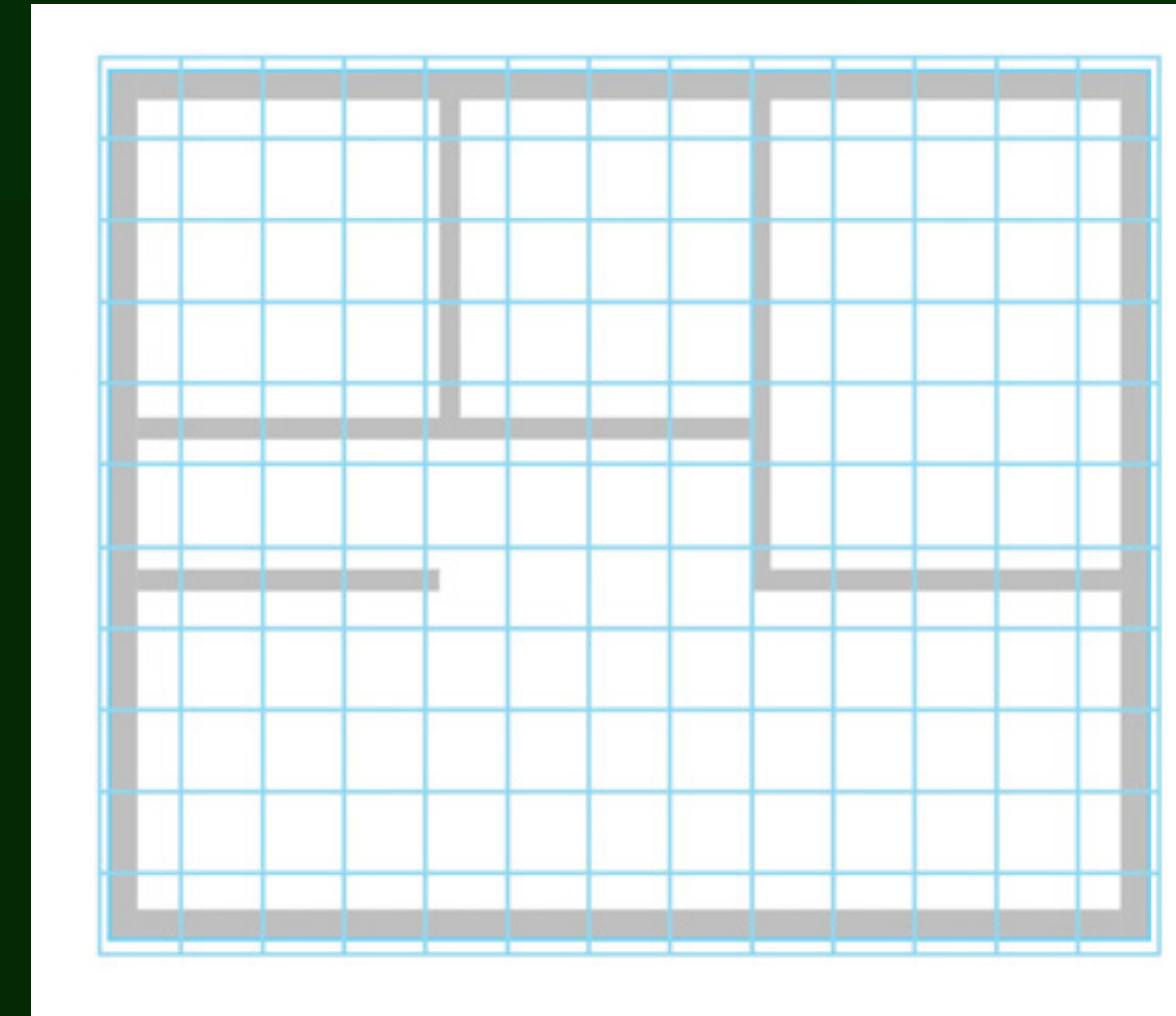
Computing storeys



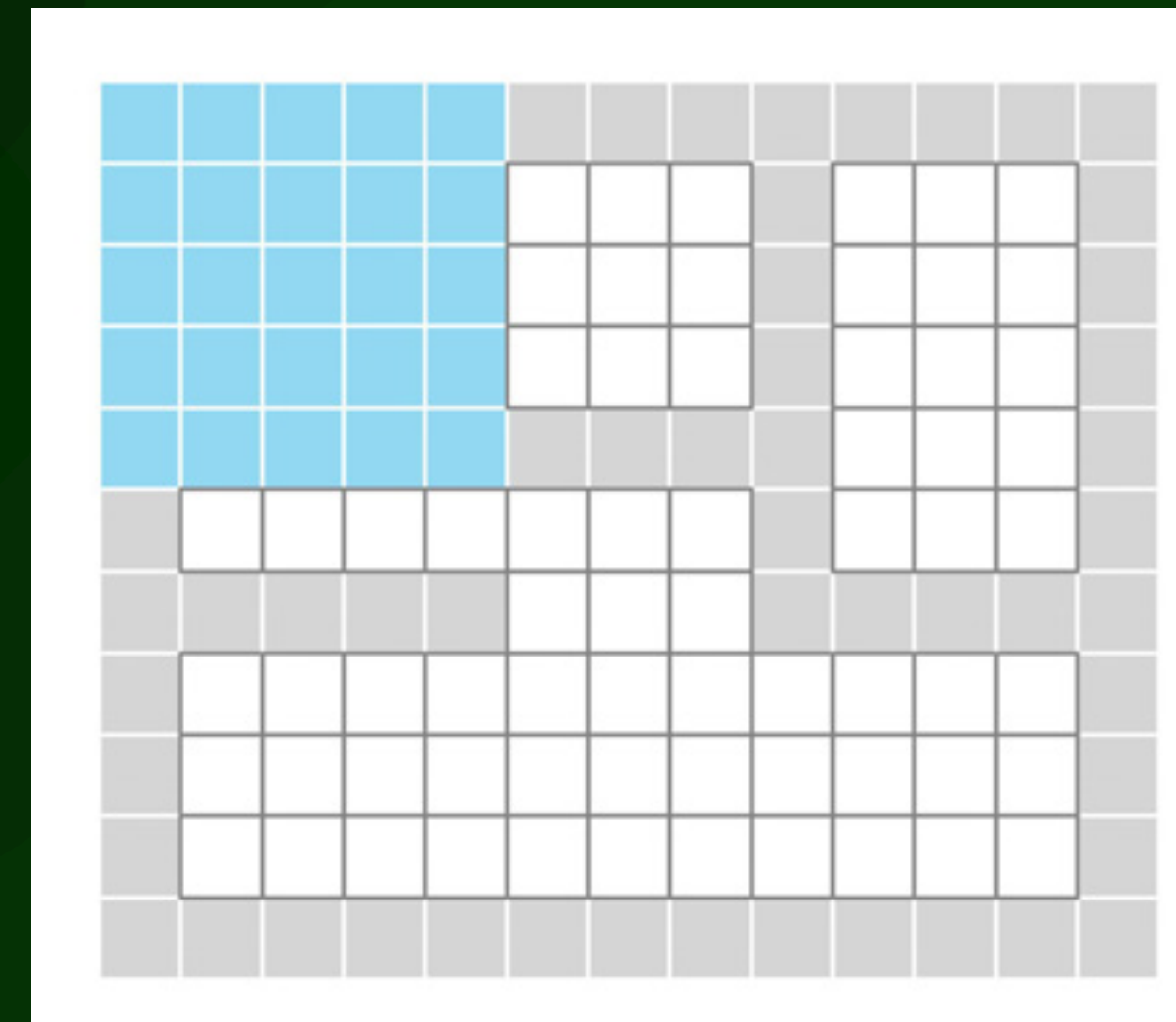
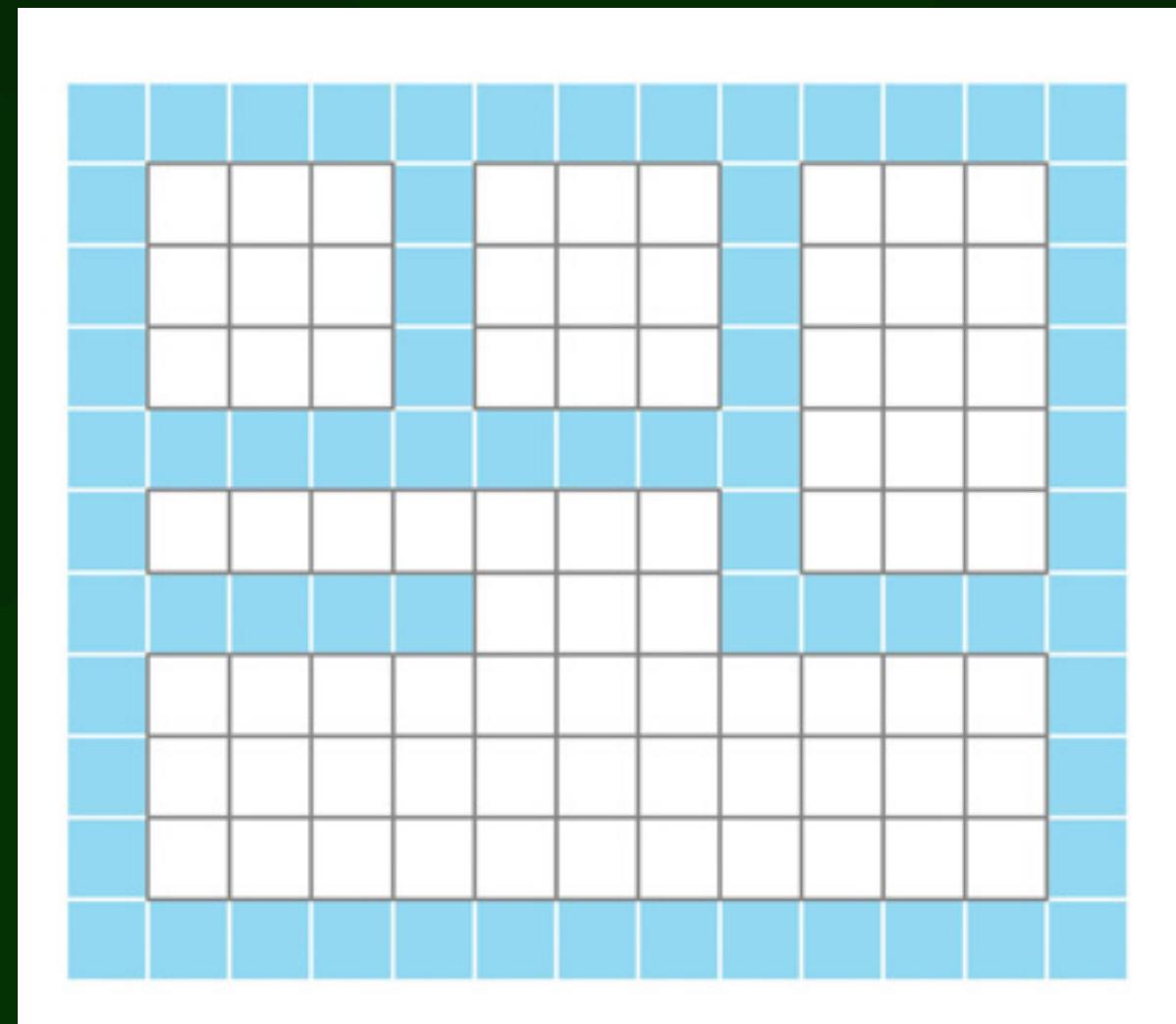
Computing rooms



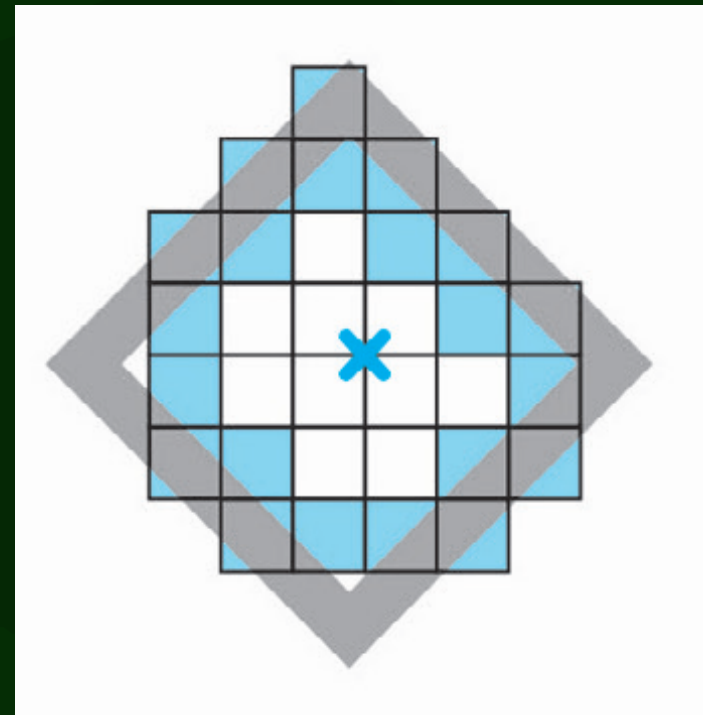
(c)



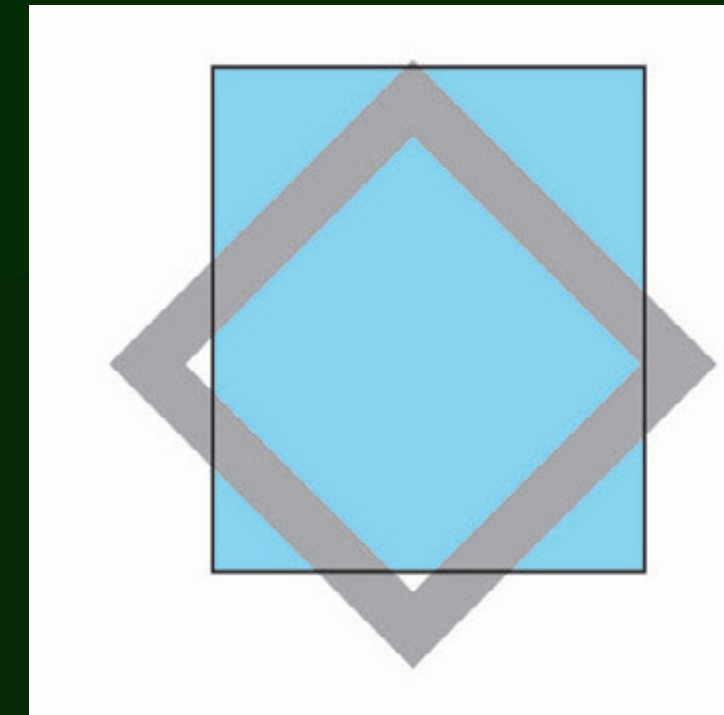
(d)



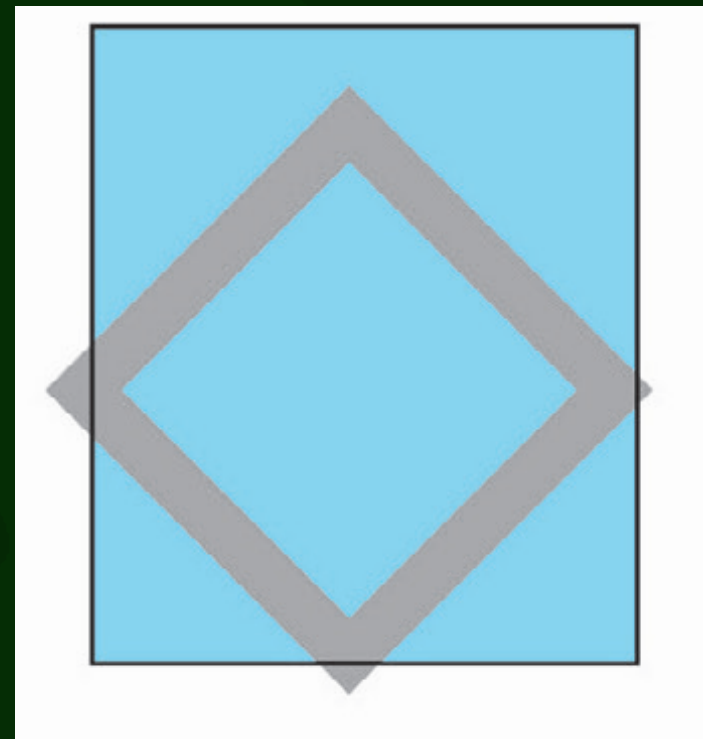
Computing rooms



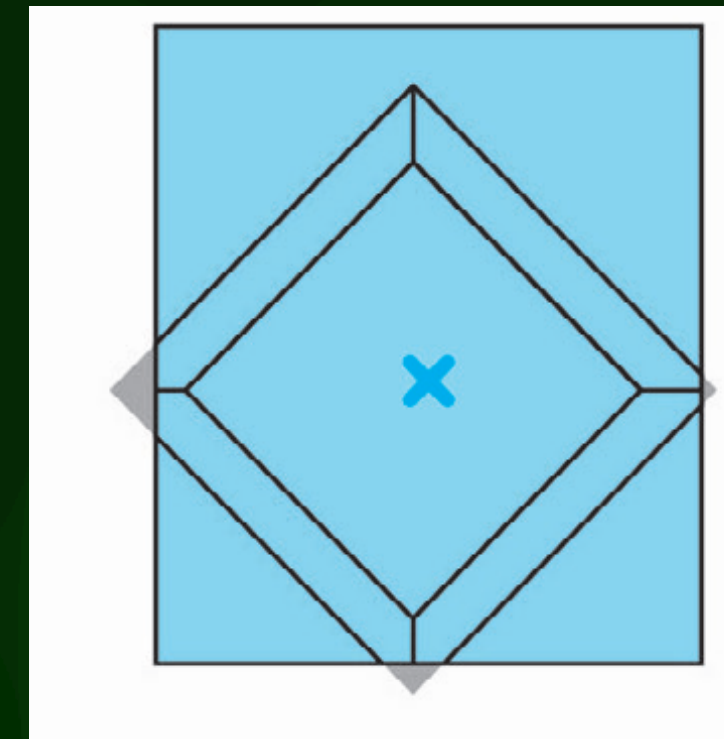
(a)



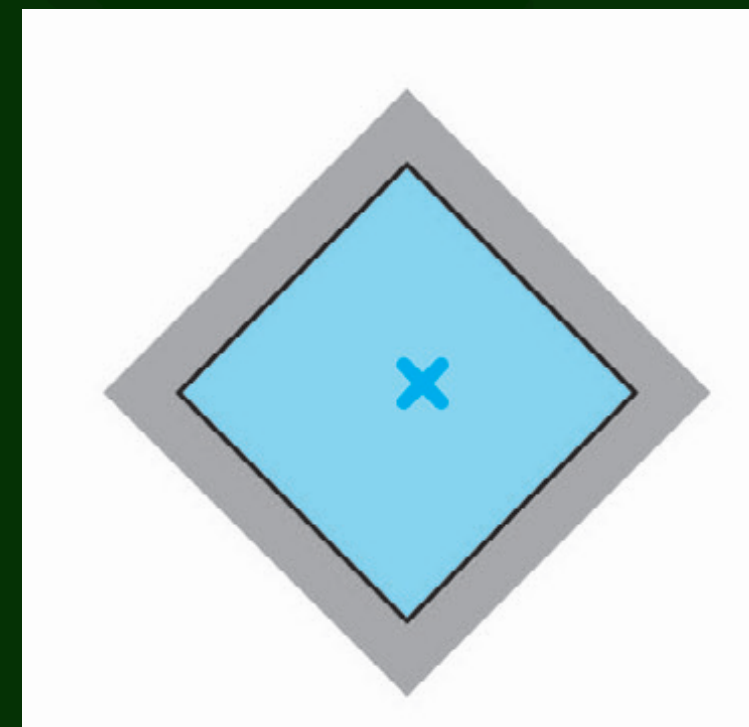
(b)



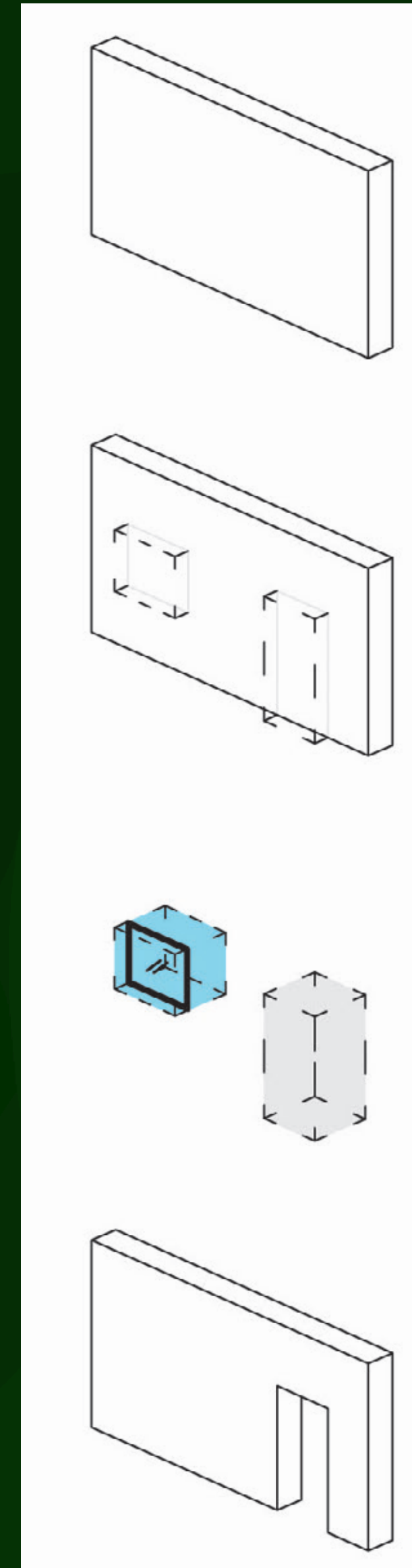
(c)



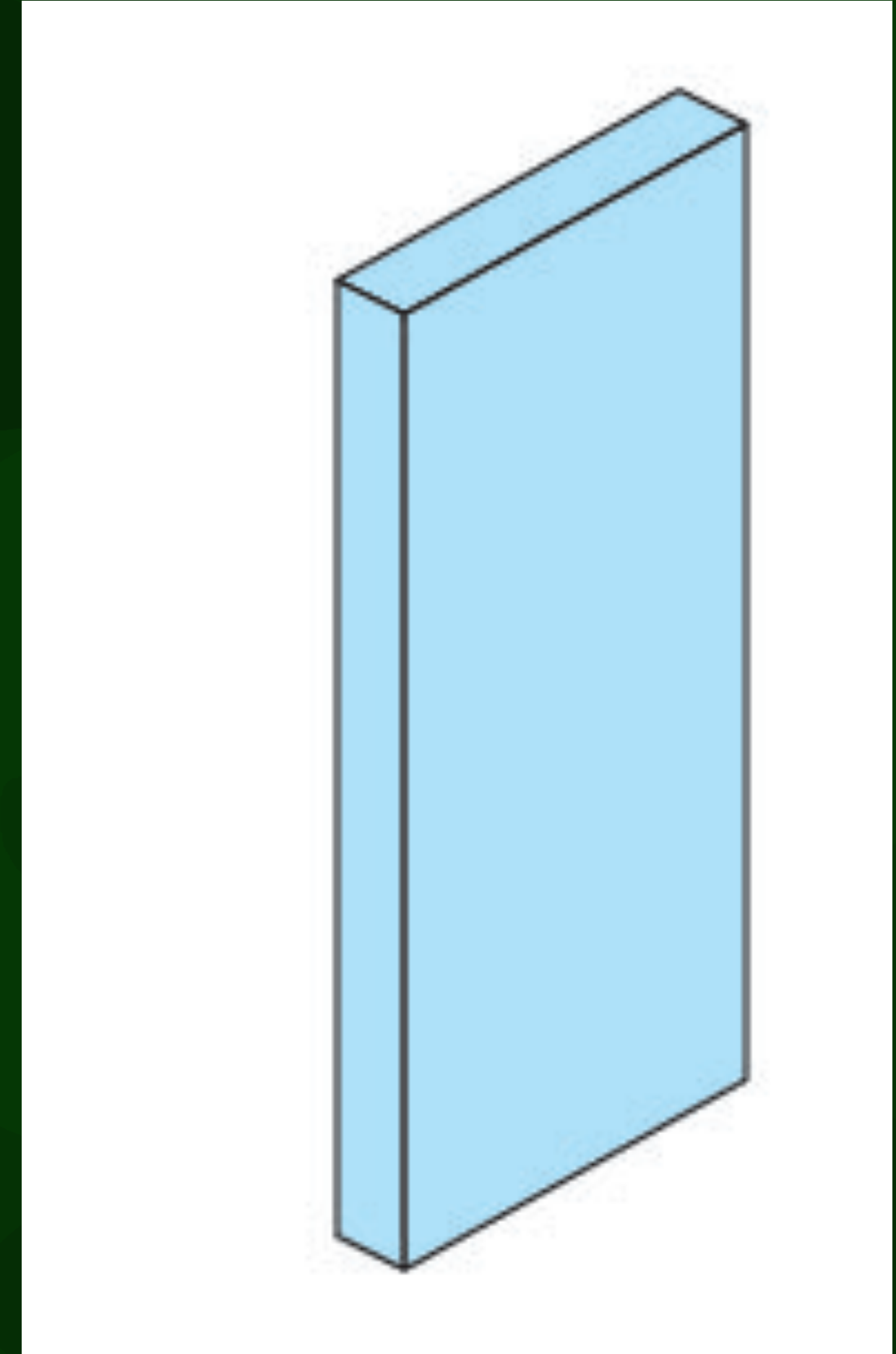
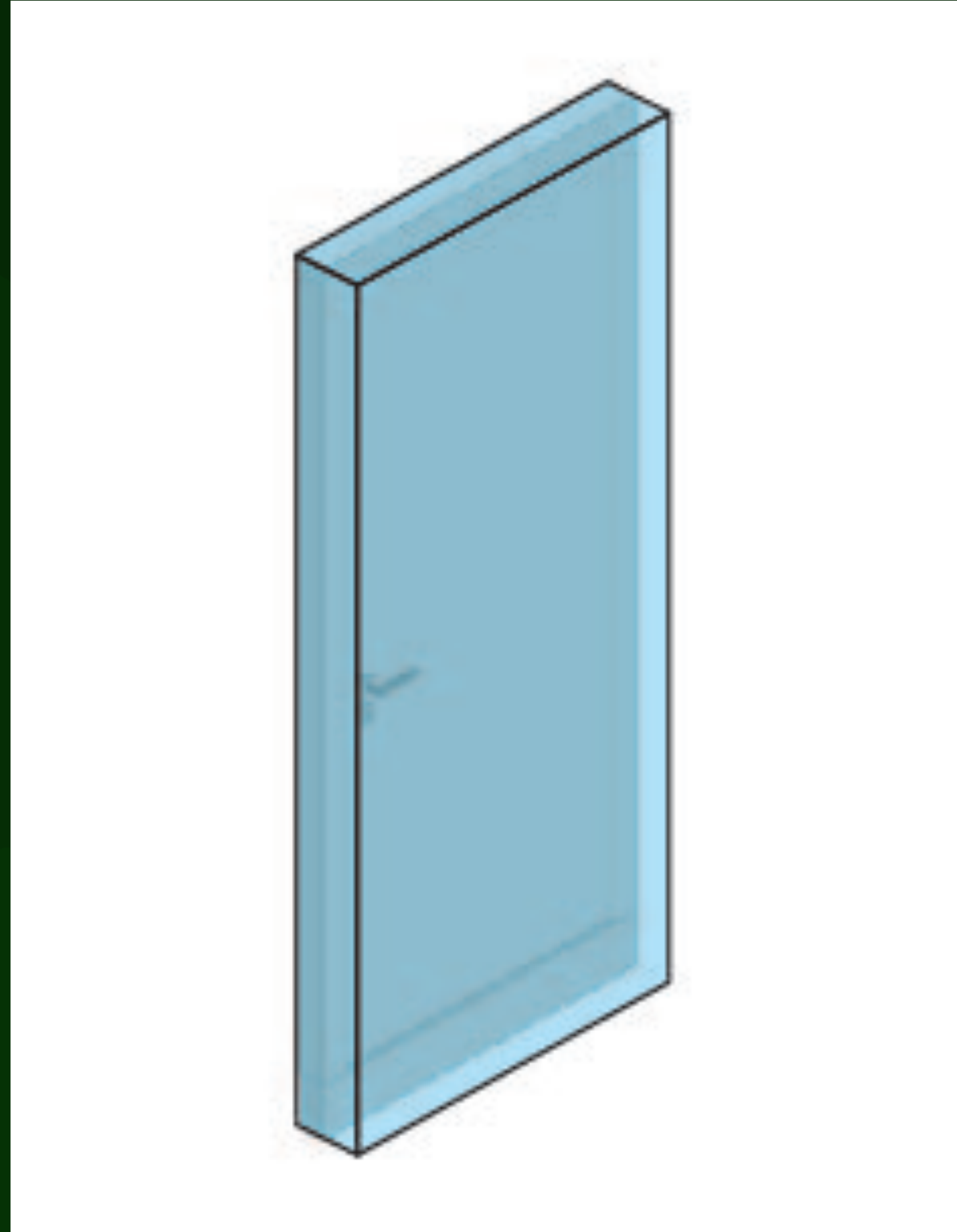
(d)



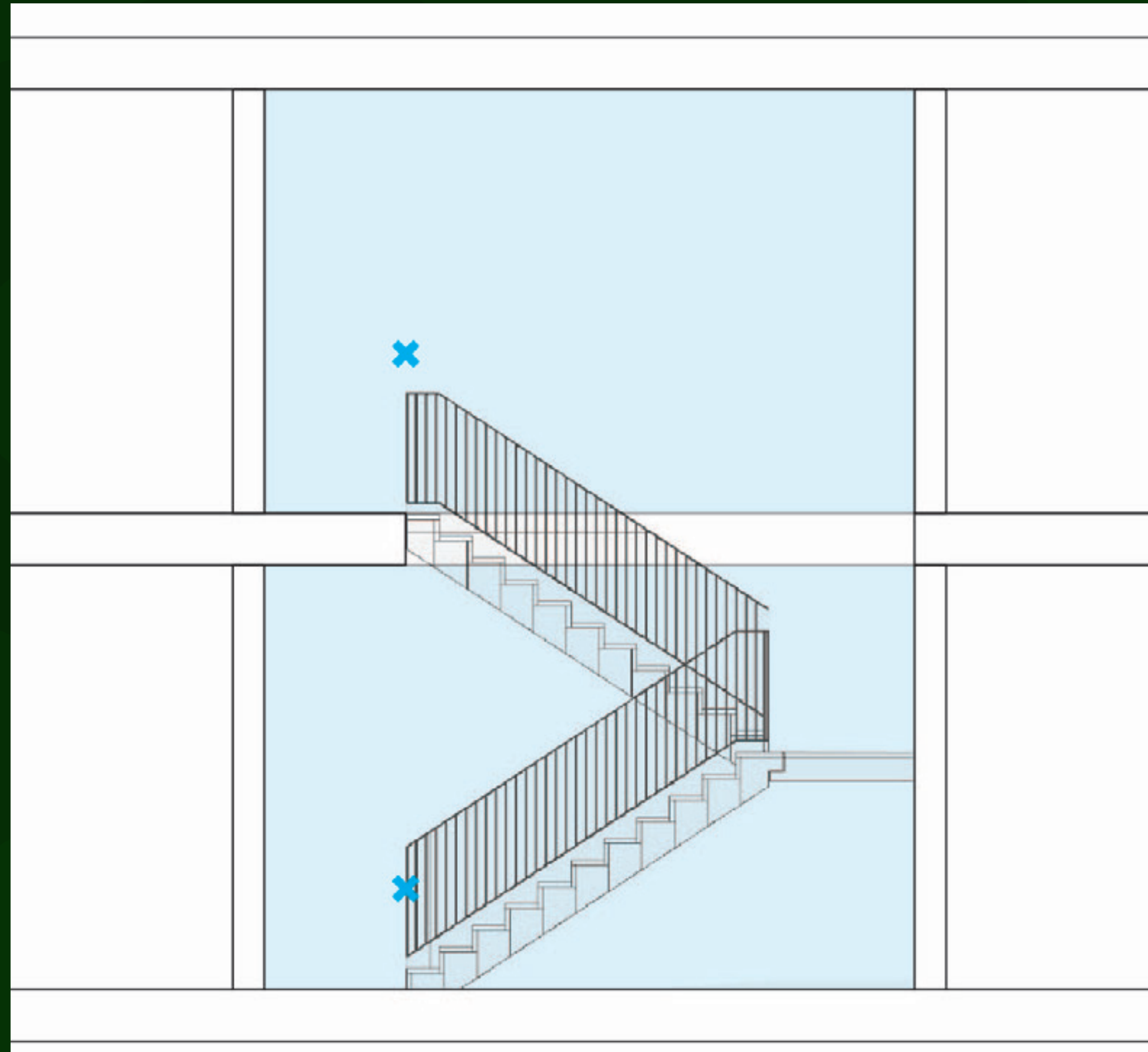
Computing rooms



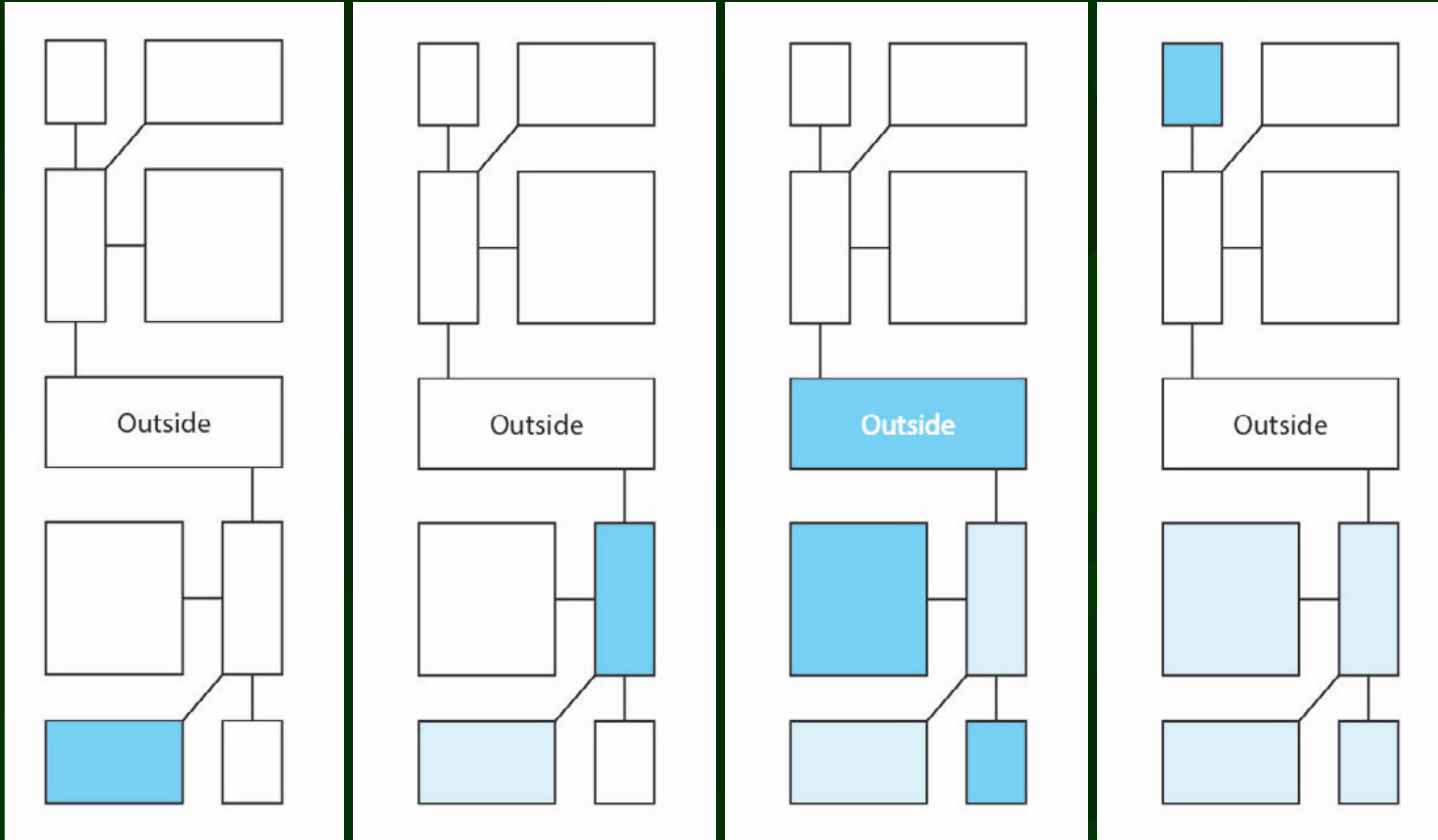
Computing rooms



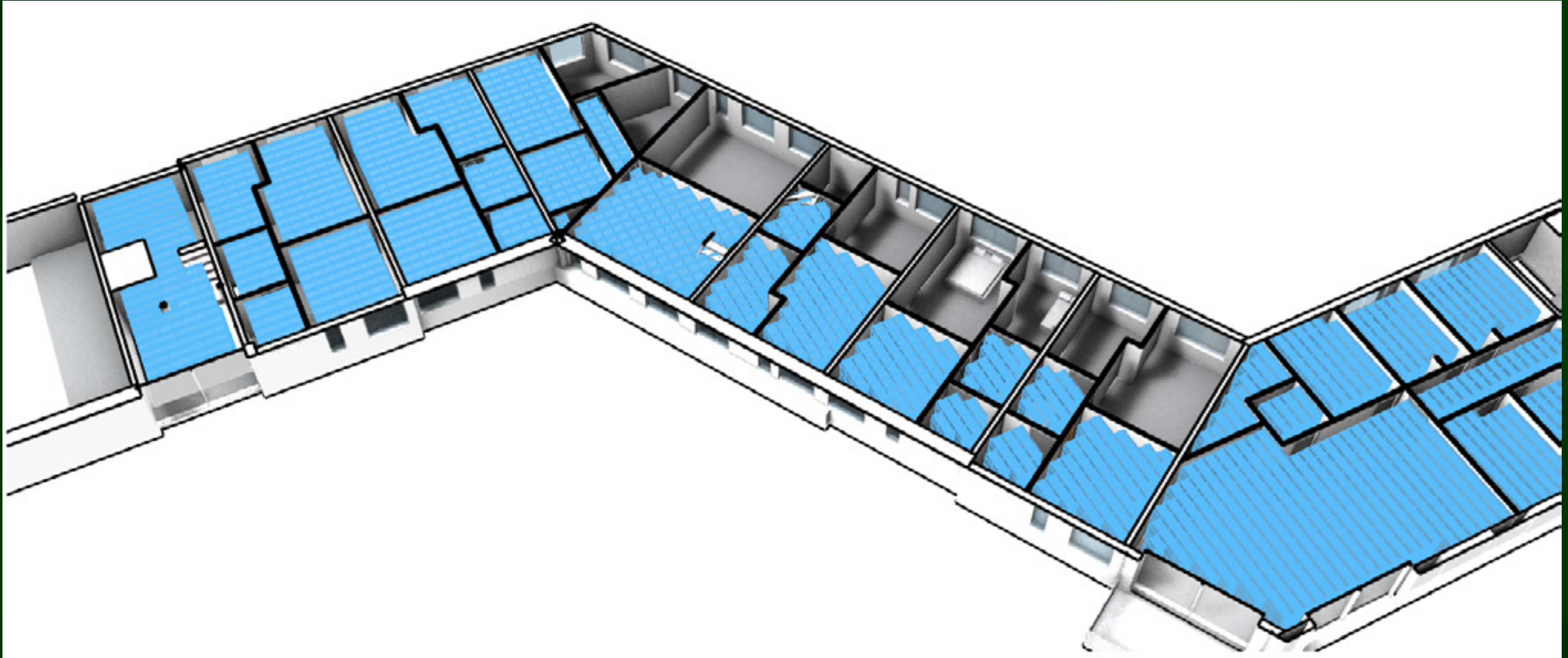
Computing rooms



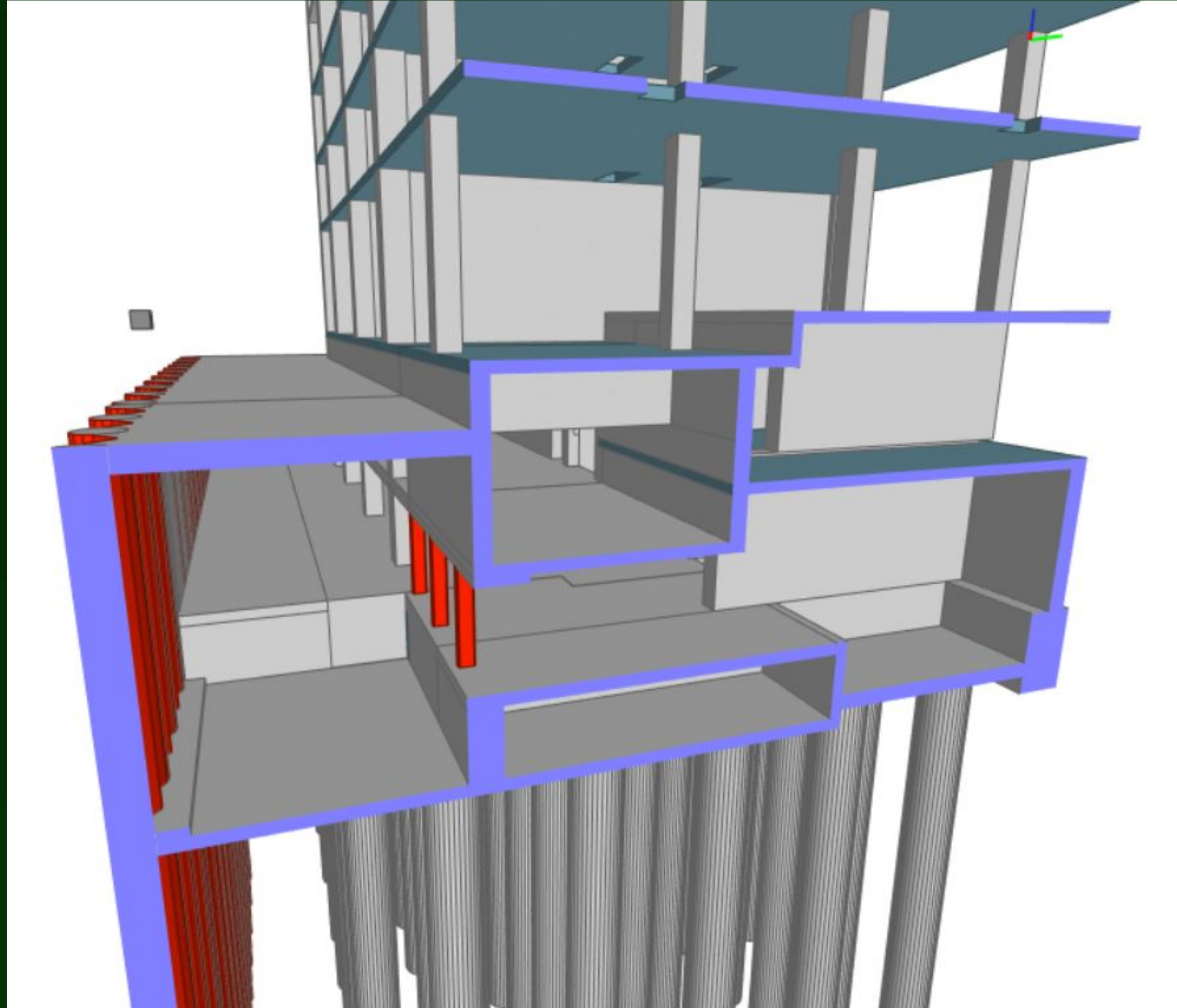
Computing apartments



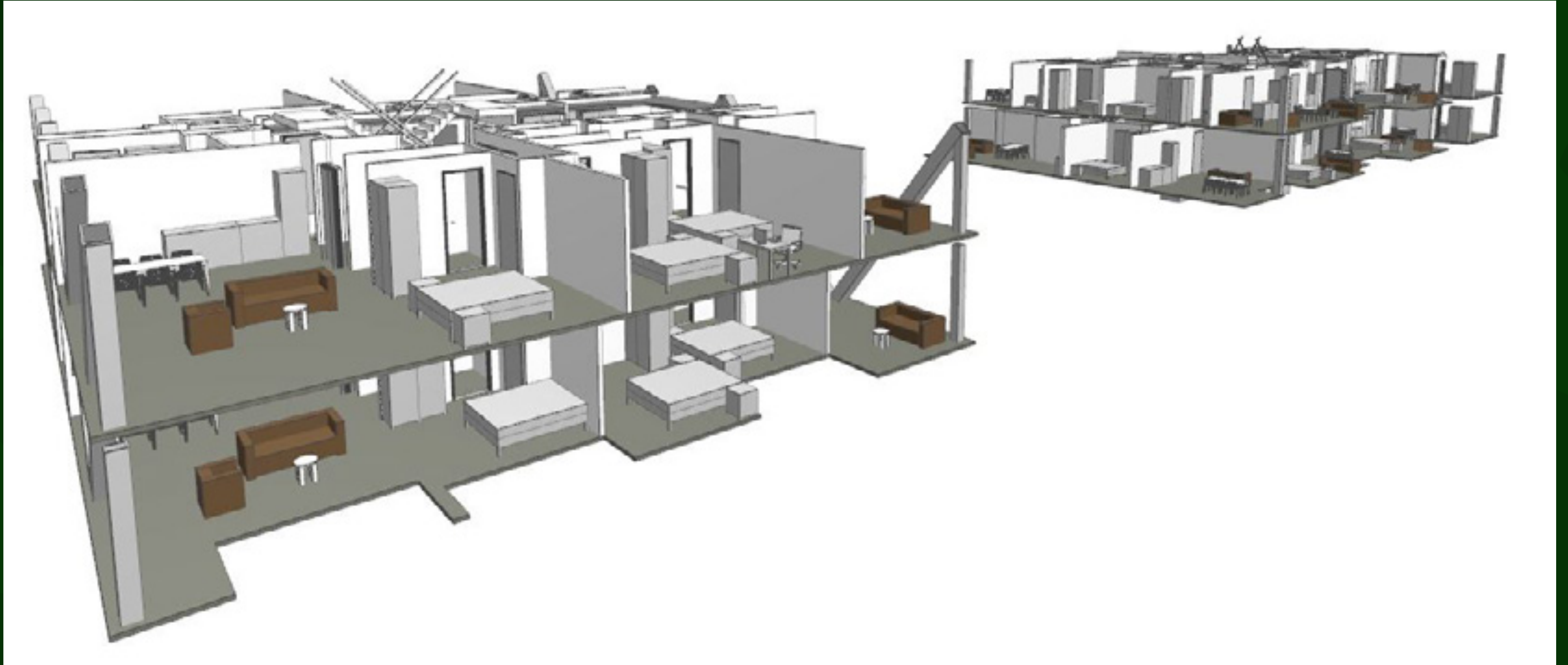
Results



Results



Results



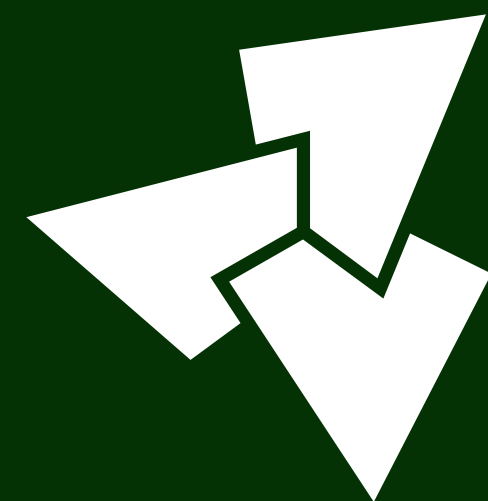
Recommendations

- GEO5021: Applications of Geomatics 2 (Modelling wind and dispersion in urban environments)
- GEO5010: Research assignment
- Your own MSc thesis

What's next?

- Wednesday:
 - Homework 2 feedback
 - Guest lecture on Digital twins for positive energy districts
- Friday: last help session (10:45-12:30)
- Next Monday: submit Homework 3
- Rest of Week 9: prepare for final exam, questions -> Discord
- Week 10:
 - Monday (22nd): Final exam 9:00-11:00 (see website for details)
 - Tuesday-Wednesday (23rd-24th): Marking... uploaded at some point on Wednesday
 - Thursday-Friday (25th-26th): Questions about your mark? Come to my office (BG.West.550) or ask on Discord

<https://3d.bk.tudelft.nl/courses/geo1004>



3D geoinformation

Department of Urbanism
Faculty of Architecture and the Built Environment
Delft University of Technology

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 Donker (MSc thesis)
- [30-48]: Damien Mulder (MSc thesis)
- [49, 51-62]: Yixin Xu (MSc thesis)

Sources of images

- [50]: Anna-Maria Ntarladima (MSc thesis)
- [63-70]: Jialun Wu (MSc thesis)
- [71-78]: Özge Tufan (MSc thesis)
- [79-91]: Jasper van der Vaart (MSc thesis)