

# 3D BAG

---

GEO1004:  
3D modelling of the built environment

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



3D geoinformation

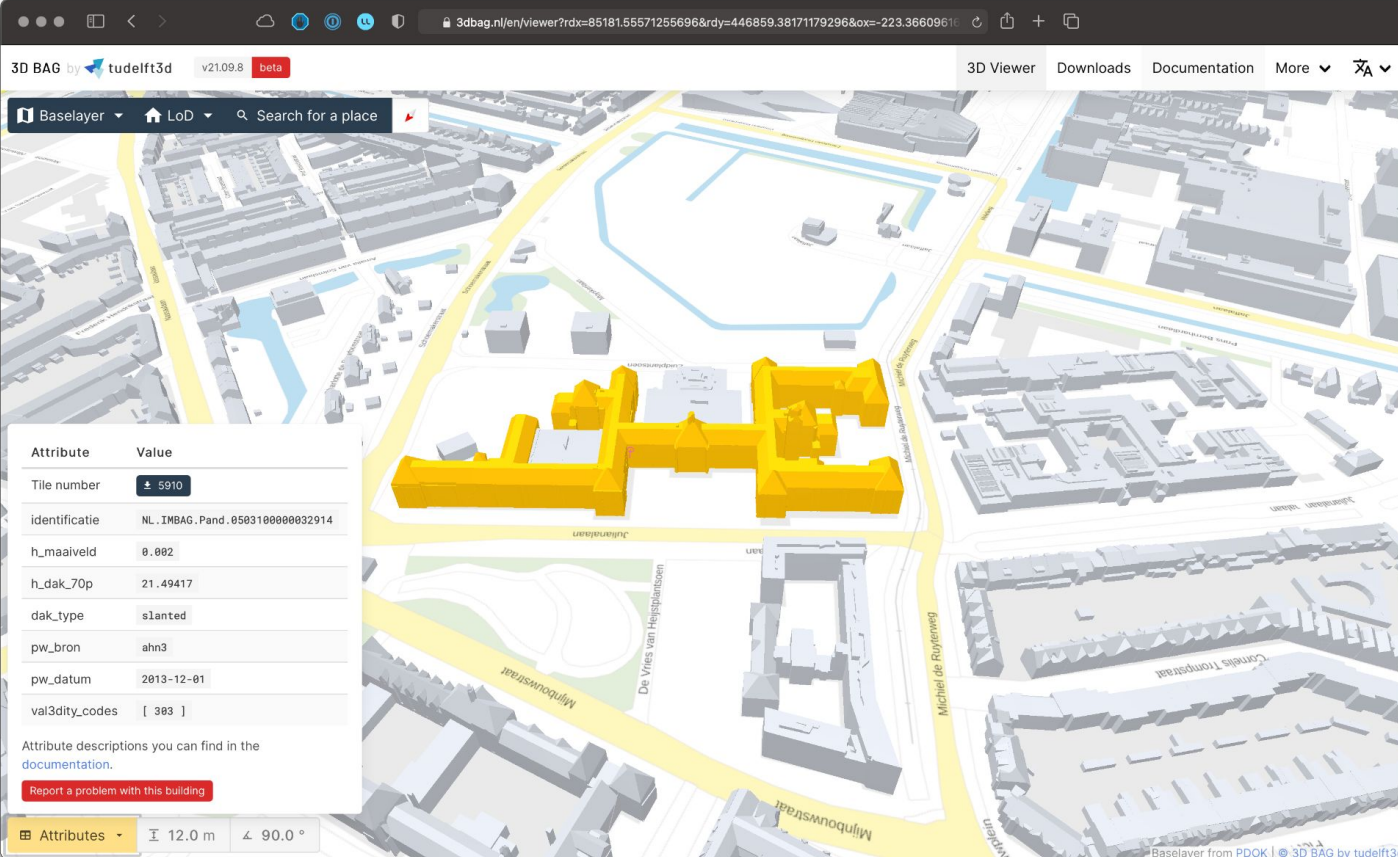
Department of Urbanism  
Faculty of Architecture and the Built Environment  
Delft University of Technology



# The 3D BAG

3dbag.nl

Data:  



3D BAG by tudelft3d v21.09.8 beta

3D Viewer Downloads Documentation More

Baselayer LoD Search for a place

Attribute	Value
Tile number	5910
identificatie	NL_IMBAG_Pand.0593100000032914
h_maaiveld	0.002
h_dak_70p	21.49417
dak_type	s1anted
pw_bron	ahn3
pw_datum	2013-12-01
val3dity_codes	[ 383 ]

Attribute descriptions you can find in the [documentation](#).

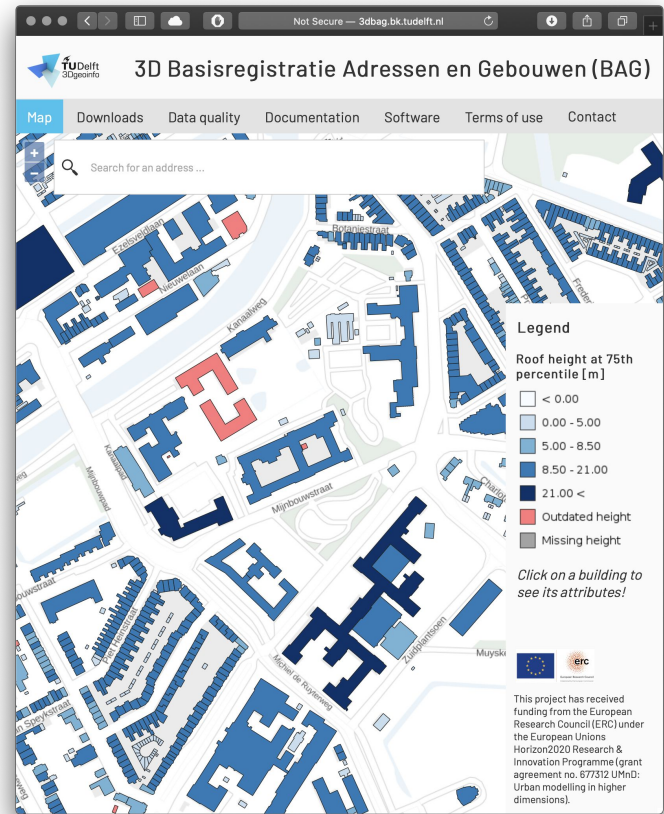
[Report a problem with this building](#)

Attributes 12.0 m 90.0°

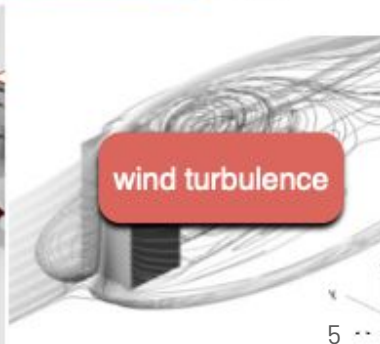
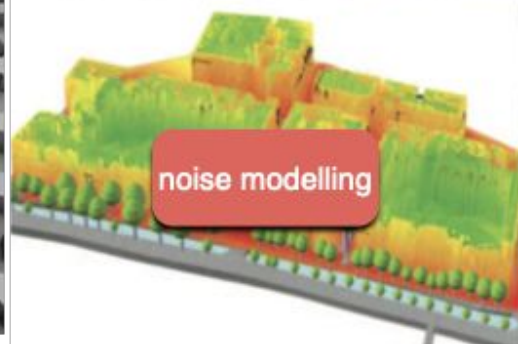
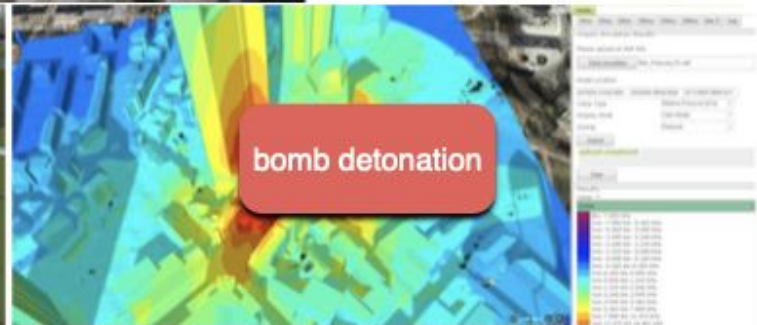
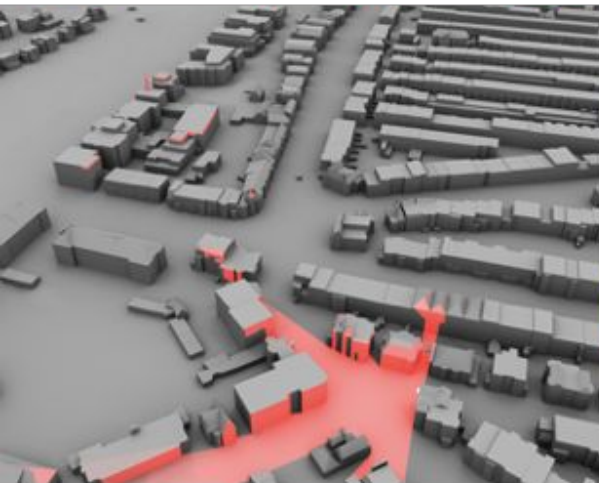
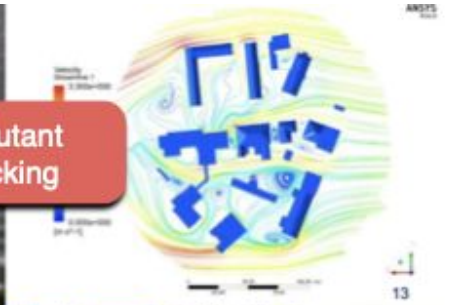
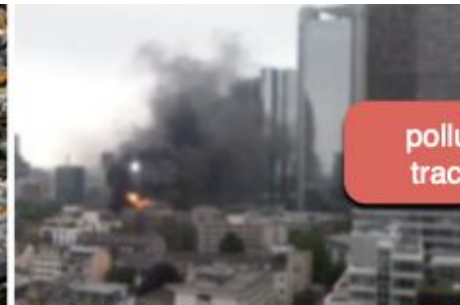
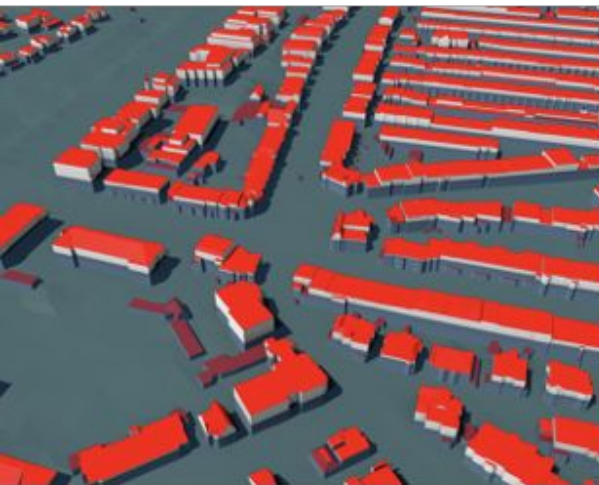
Baselayer from PDOK | 3D BAG by tudelft3d

# A bit of background...

- Developed in 3D geoinformation group
  - Ravi Peters (building reconstruction, 3D viewer)
  - Balázs Dukai (data management, automation)
  - Stelios Vitalis and Jordi Liempt (3D viewer)
- Prior to v2 we had v1
  - Only LoD1.2
  - Used by practitioners, much feedback
- Co-developments within several research projects
  - Initial request for LoD1.3 models for Noise simulation NL

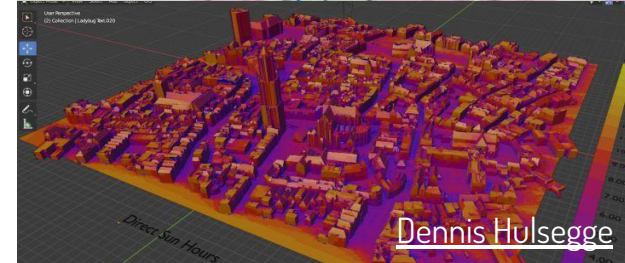
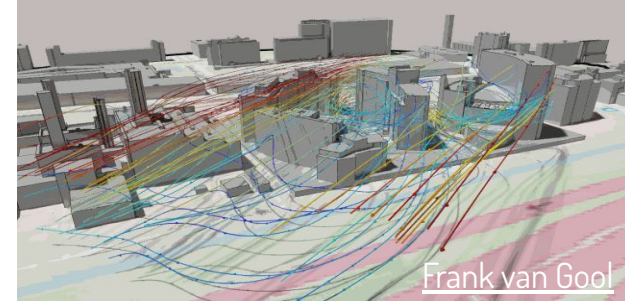
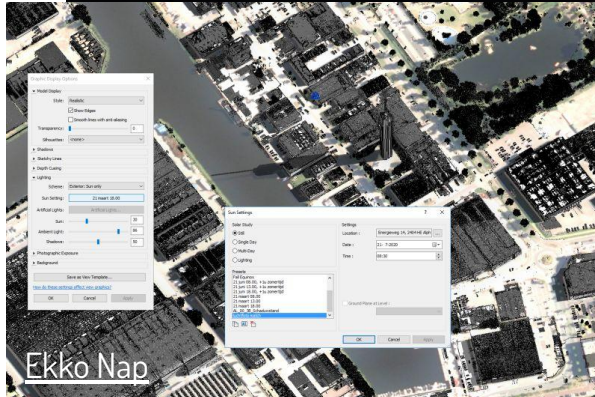
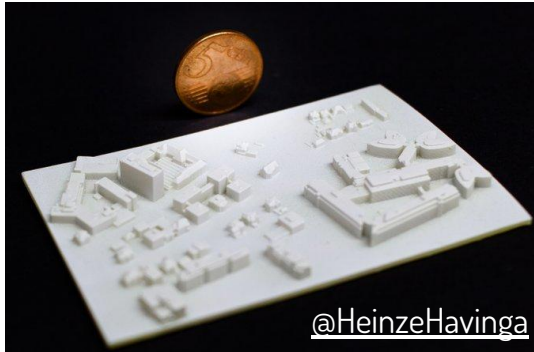


3DBAG v1



# 3D BAG in practice

<https://docs.3dbag.nl/en/overview/media/>



# 3D BAG behind the scenes

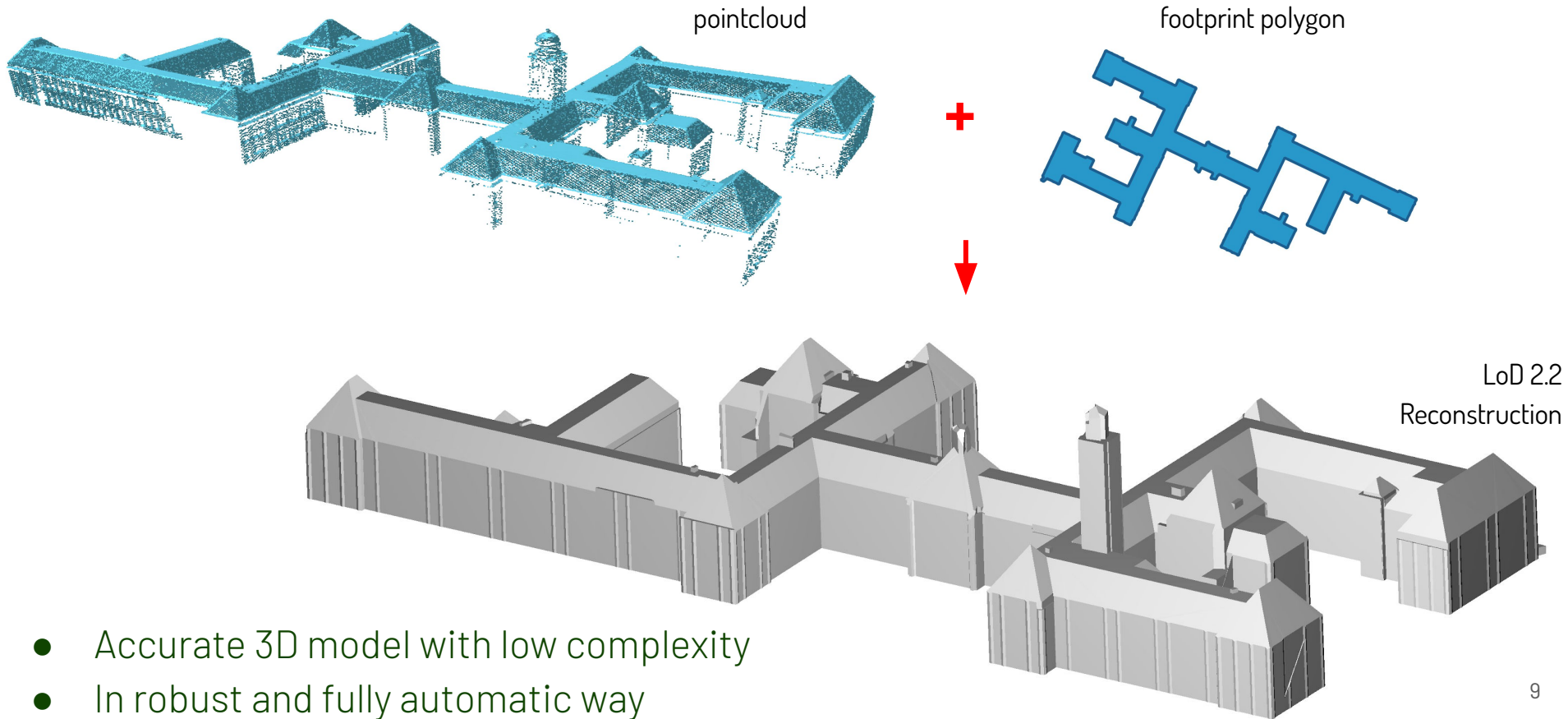
Several components

- **Reconstruction algorithm**
- Automation tooling, databases
- 3D webviewer + download services

# Reconstruction algorithm



# Building reconstruction



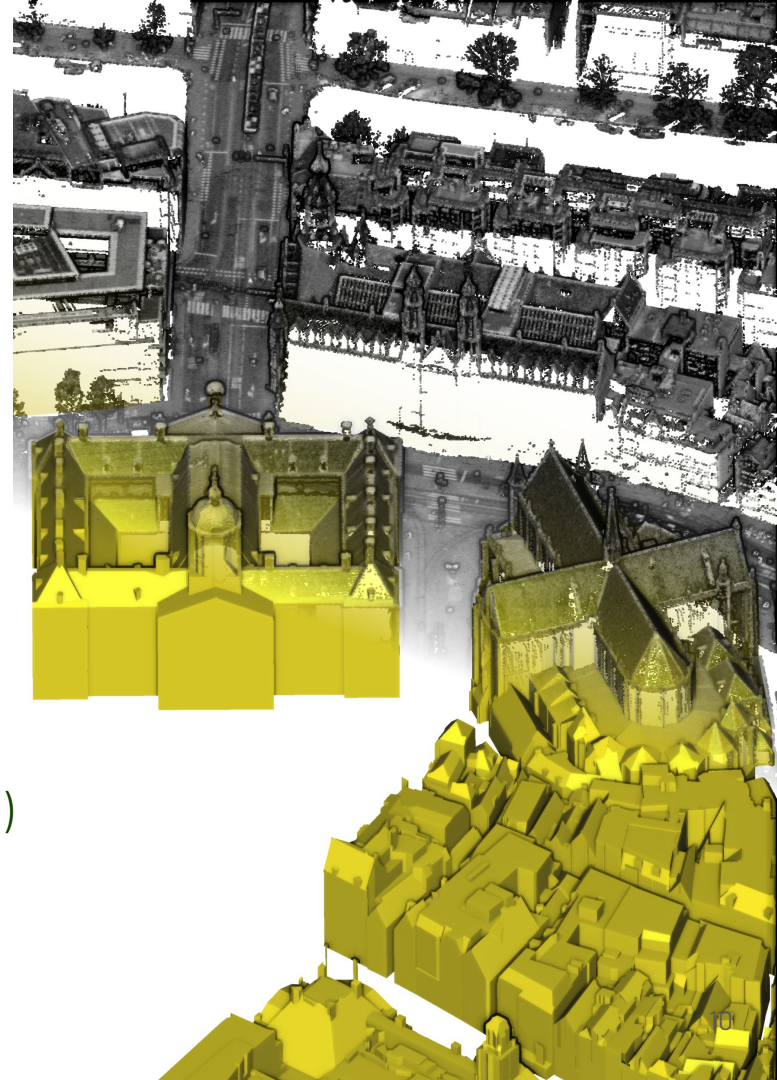
# Open data in the Netherlands

**BAG** <https://www.kadaster.nl/bag>

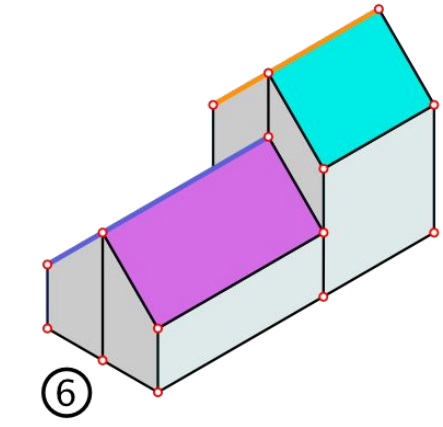
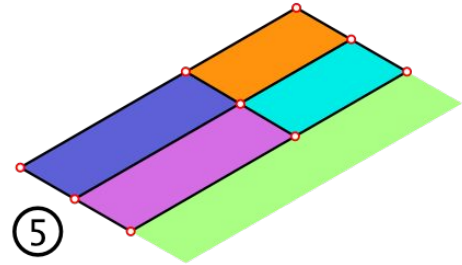
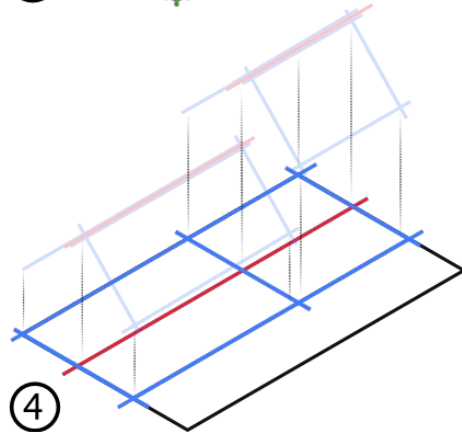
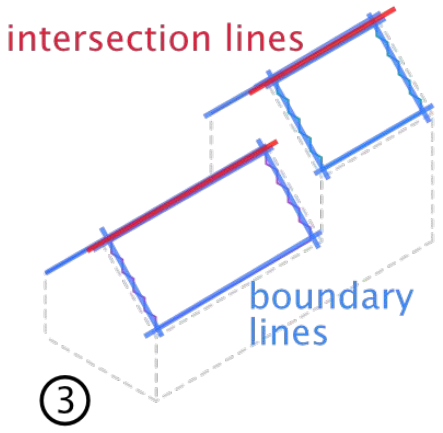
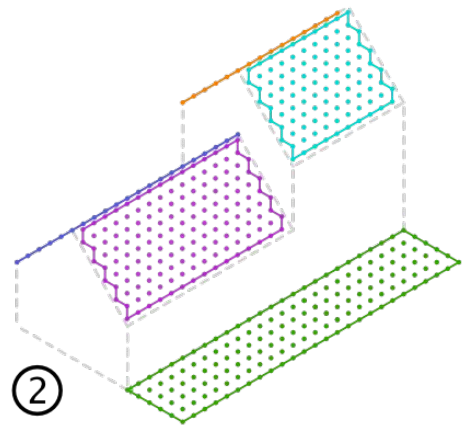
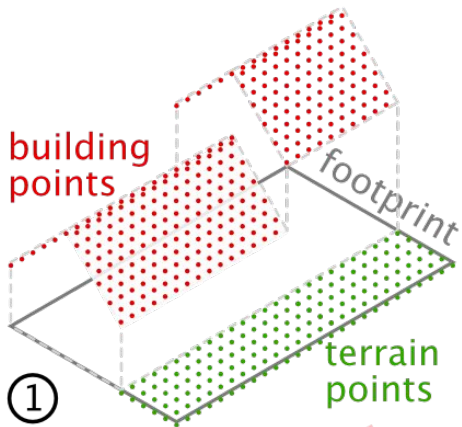
up-to-date building polygons + attributes  
largest extent → roofprint + underground  
positional accuracy 30cm

**AHN** <https://ahn.nl>

classified point cloud  
positional accuracy ~23cm (height and planimetric)  
8-15 pts/m<sup>2</sup> for buildings  
occlusion and other no-data areas

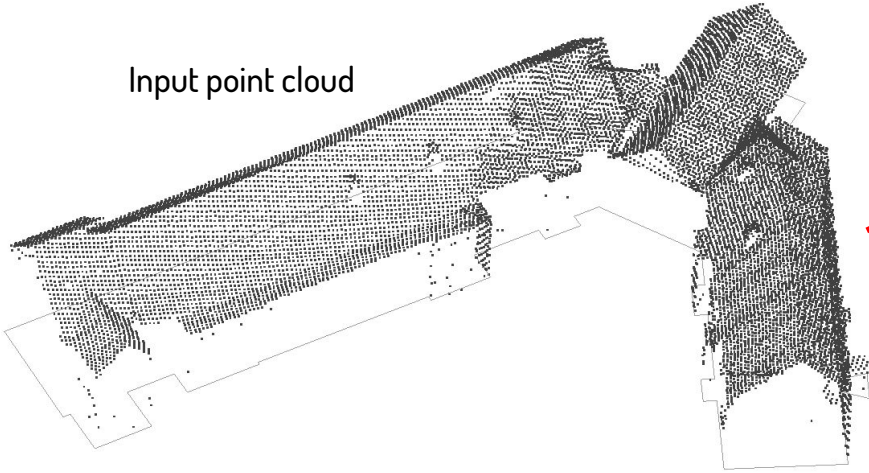


# Overview building reconstruction method

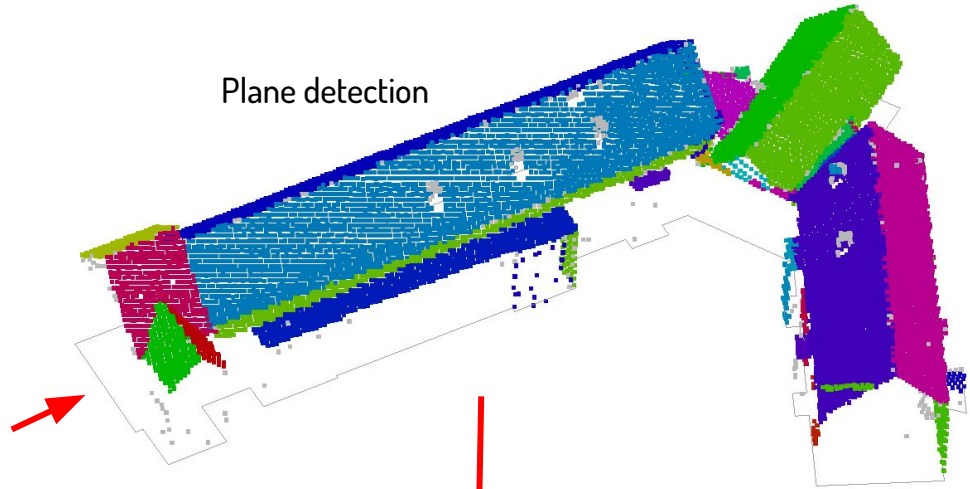


# Feature extraction

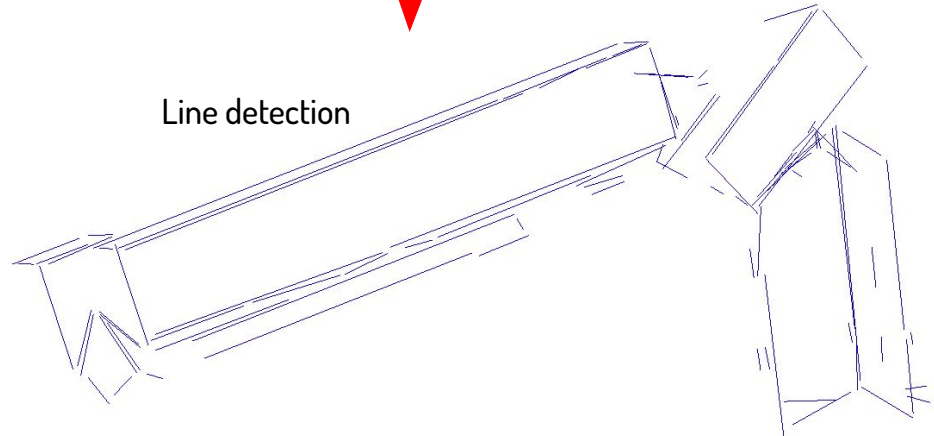
Input point cloud



Plane detection

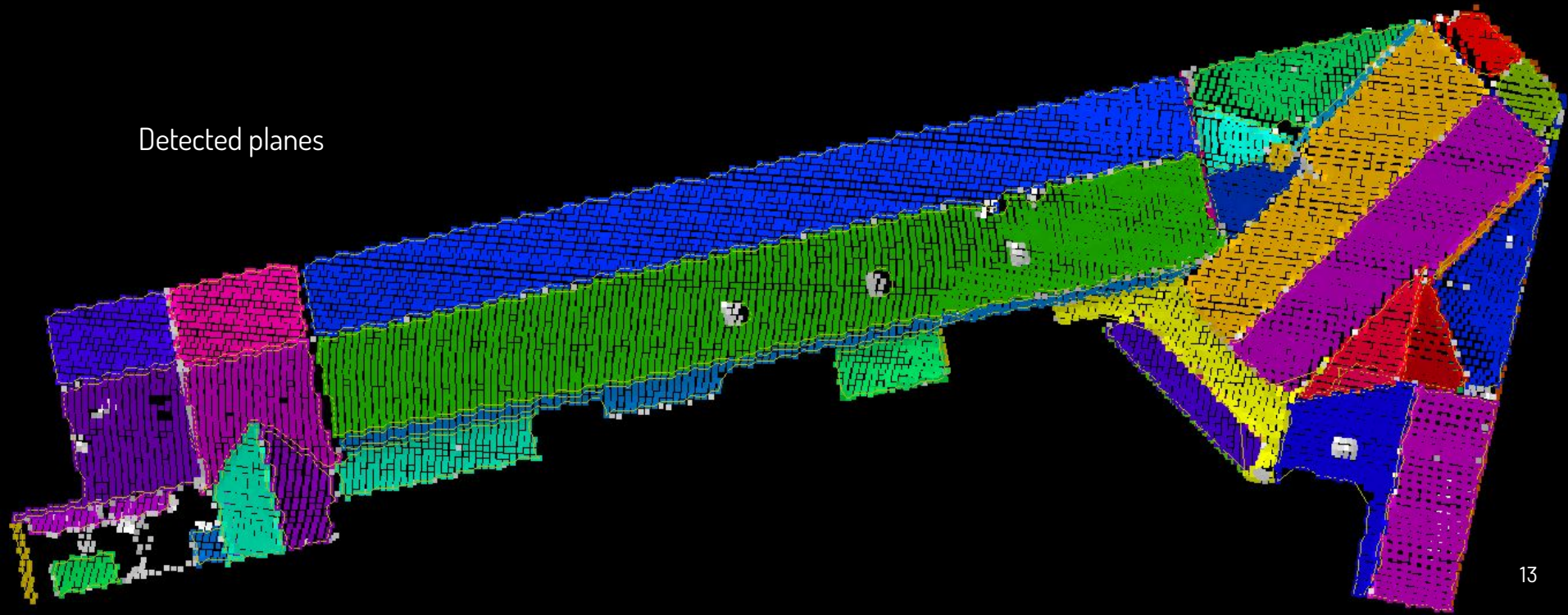


Line detection



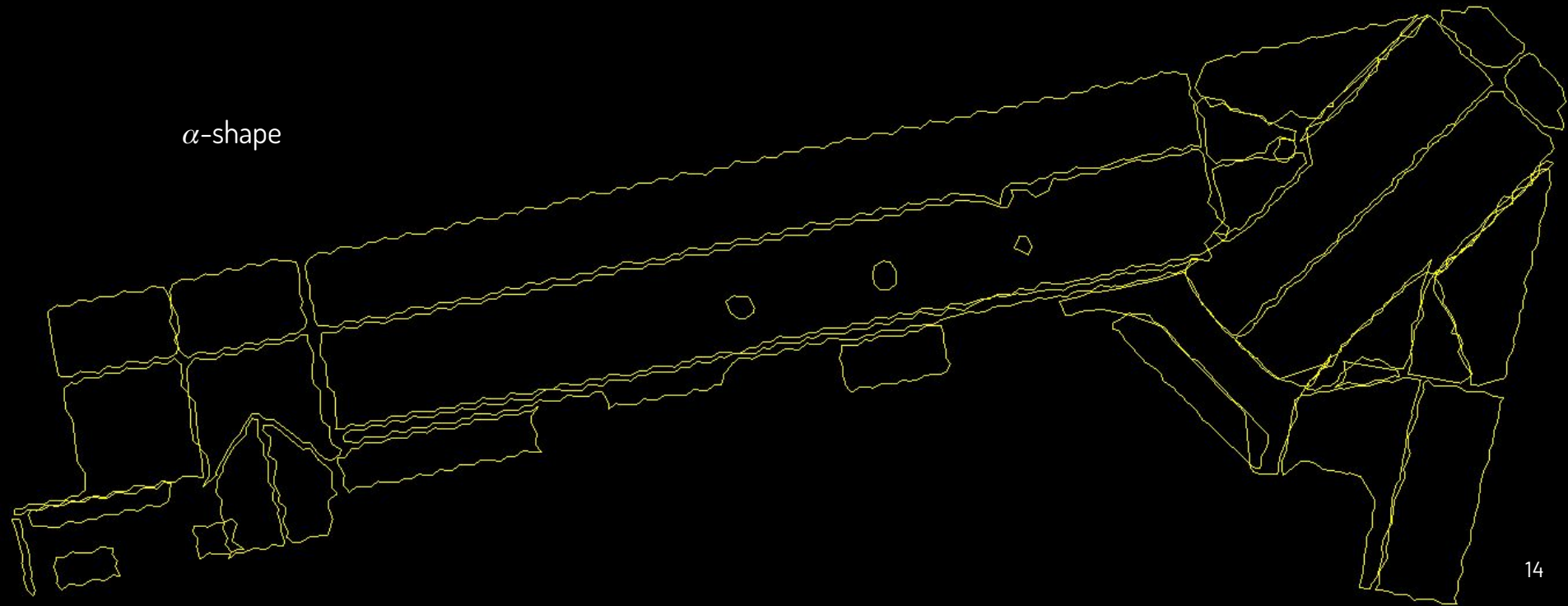
# Feature extraction

Detected planes



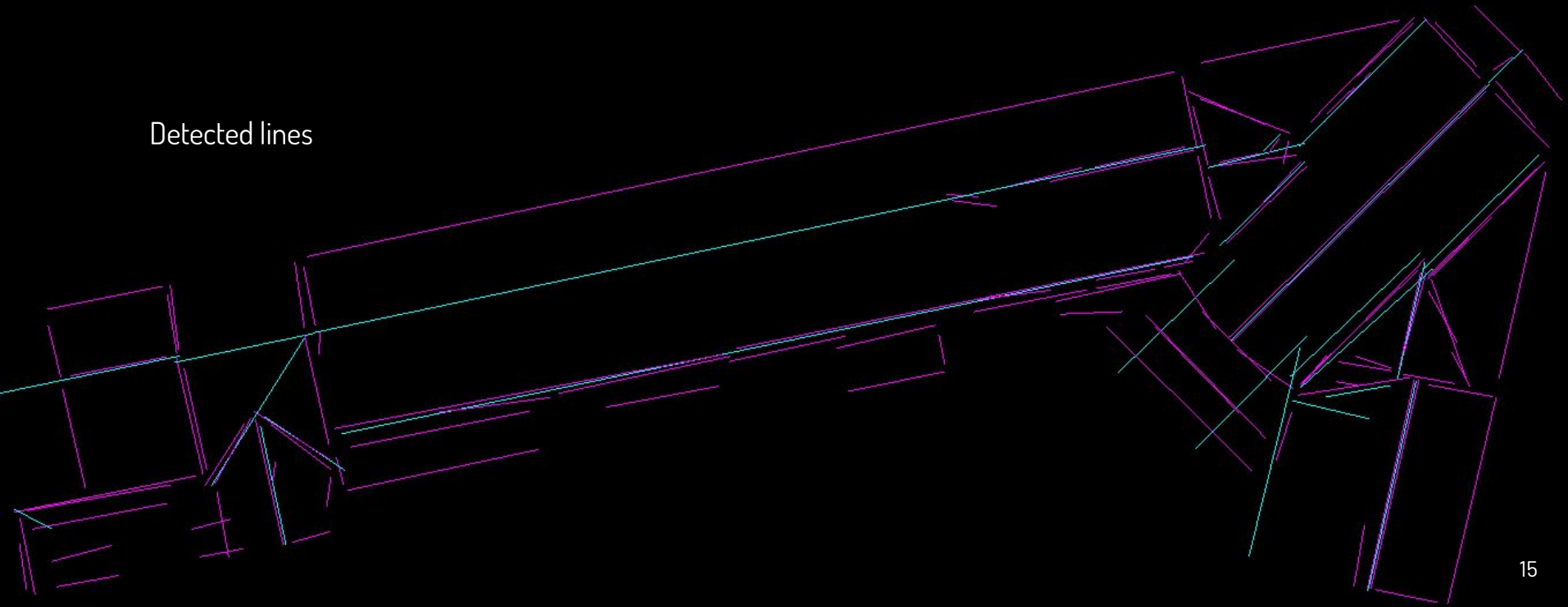
# Feature extraction

$\alpha$ -shape



# Feature extraction

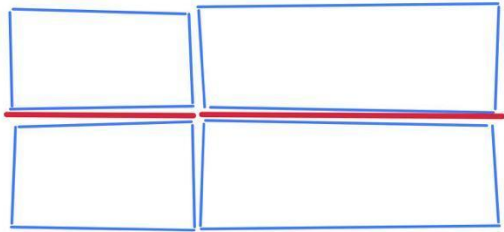
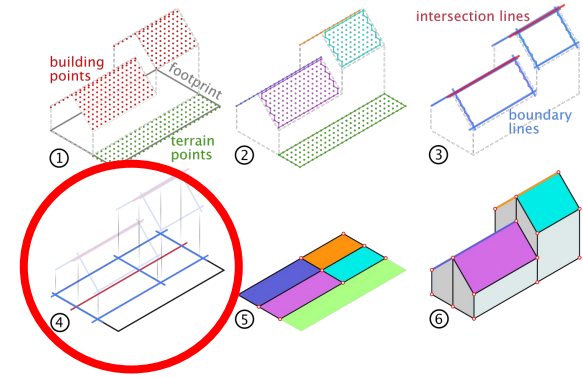
Detected lines



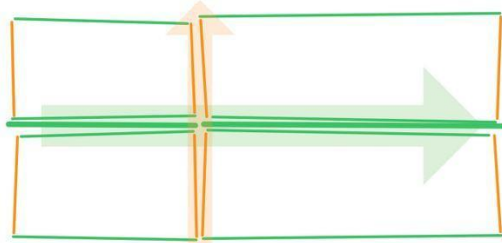
# Line regularisation

Using 2-step hierarchical clustering

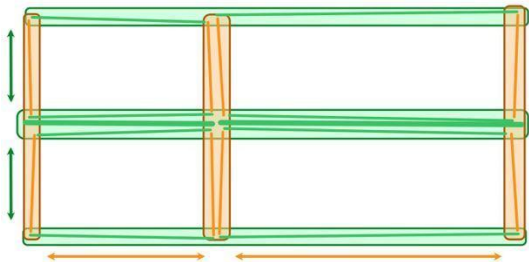
1. Based on line orientation
2. Based on euclidean distance within orientation clusters



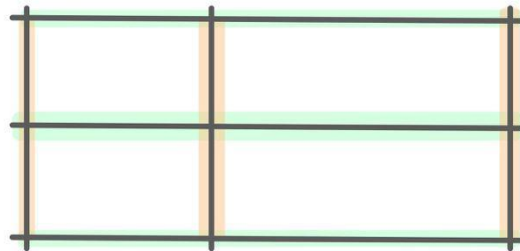
(a) Detected lines



(b) Orientation clustering



(c) Distance clustering

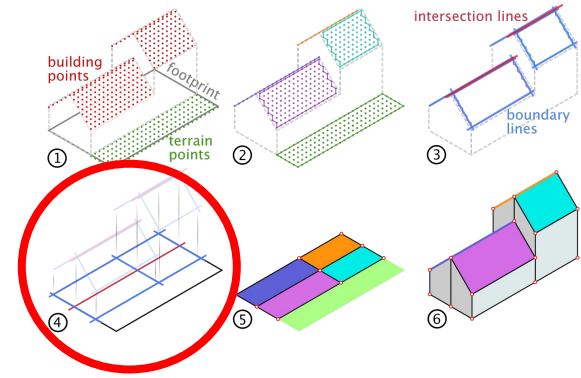
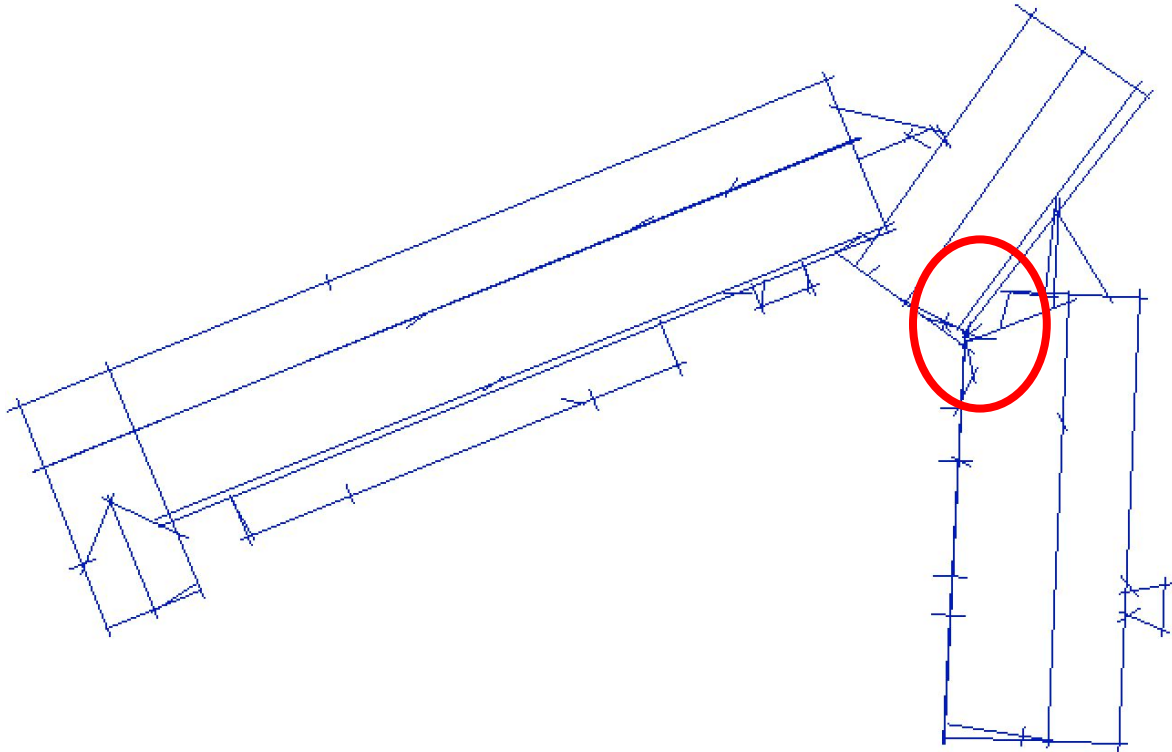


(d) Regularised lines



# Initial roof partition

Still many small faces



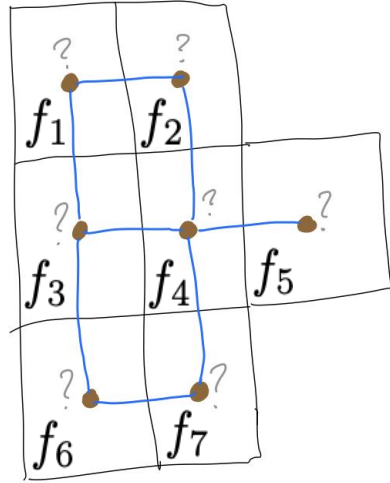
# Graph-cut optimisation

[Zebedin et al. \(2008\)](#)

Not for exam!

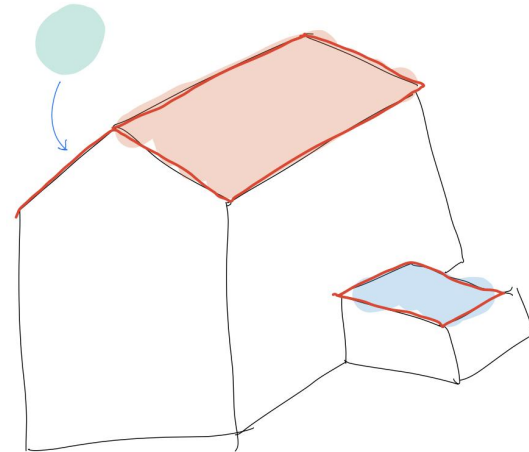
$$E(f) = \sum_{p \in P} D_p(f_p) + \lambda \cdot \sum_{\{p,q\} \in N} V_{p,q}(f_p, f_q)$$

Dual graph of planar arrangement



possible labels:

1. 
2. 
3. 



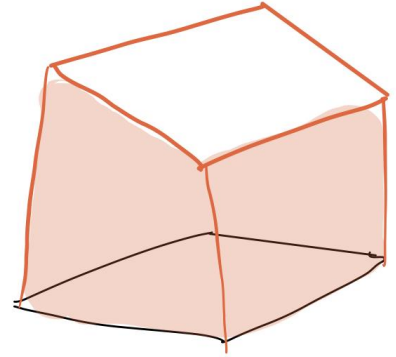
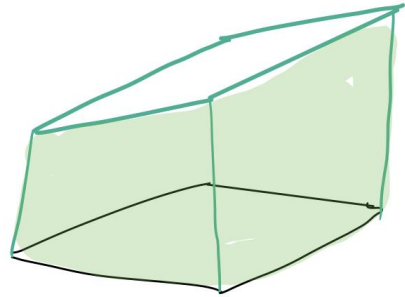
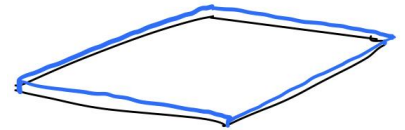
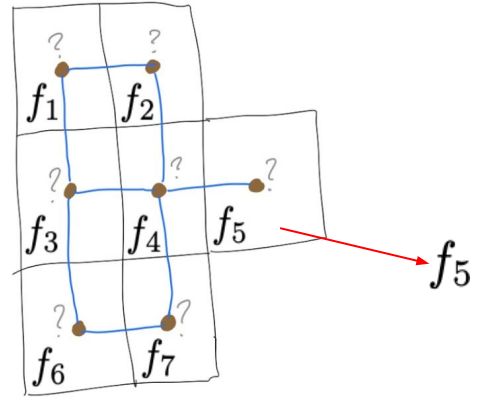
# Graph-cut optimisation

$$E(f) = \sum_{p \in P} D_p(f_p) + \lambda \cdot \sum_{\{p,q\} \in N} V_{p,q}(f_p, f_q)$$

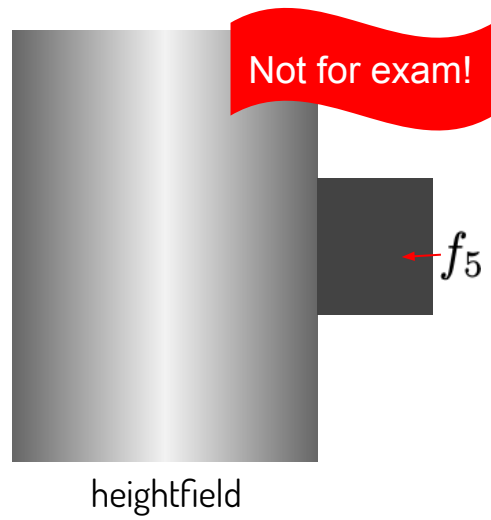
Data term:

Volume between candidate planes and 2.5D heightfield of point cloud at a face

Maximises data fit



Volume wrt each candidate plane



heightfield

# Graph-cut optimisation

Not for exam!

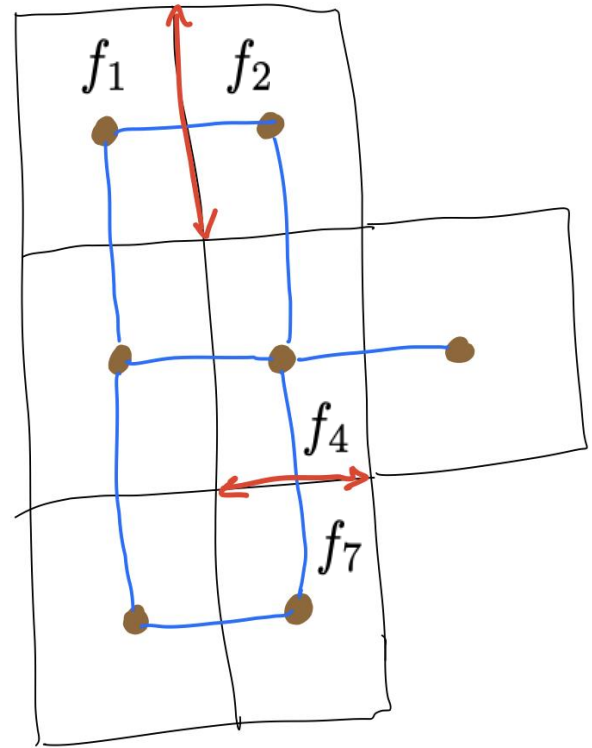
$$E(f) = \sum_{p \in P} D_p(f_p) + \lambda \cdot \sum_{\{p,q\} \in N} V_{p,q}(f_p, f_q)$$

$$V_{p,q}(f_p, f_q) = \begin{cases} \text{length}(\text{border}(p, q)) & \text{if } f_p \neq f_q \\ 0 & \text{if } f_p = f_q \end{cases}$$

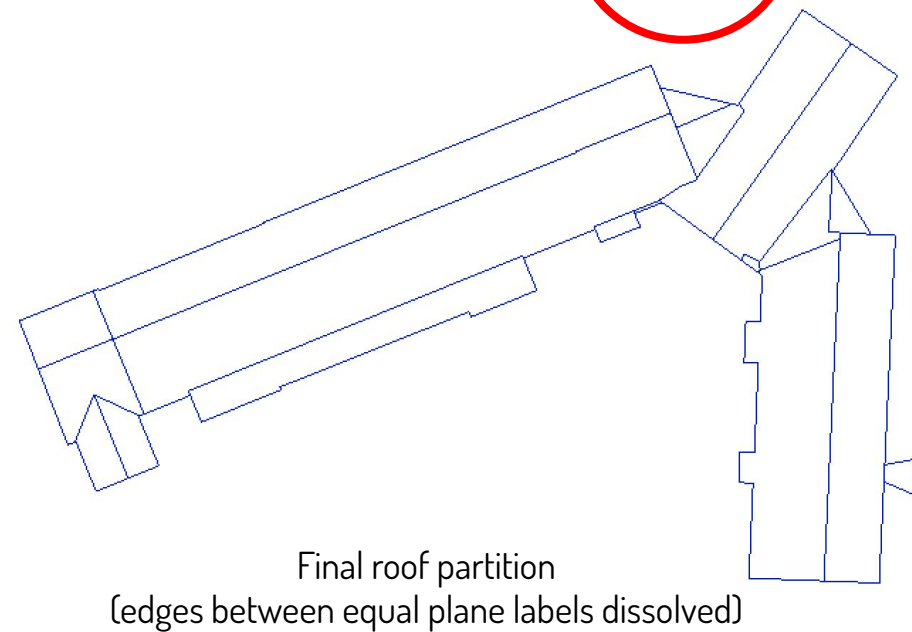
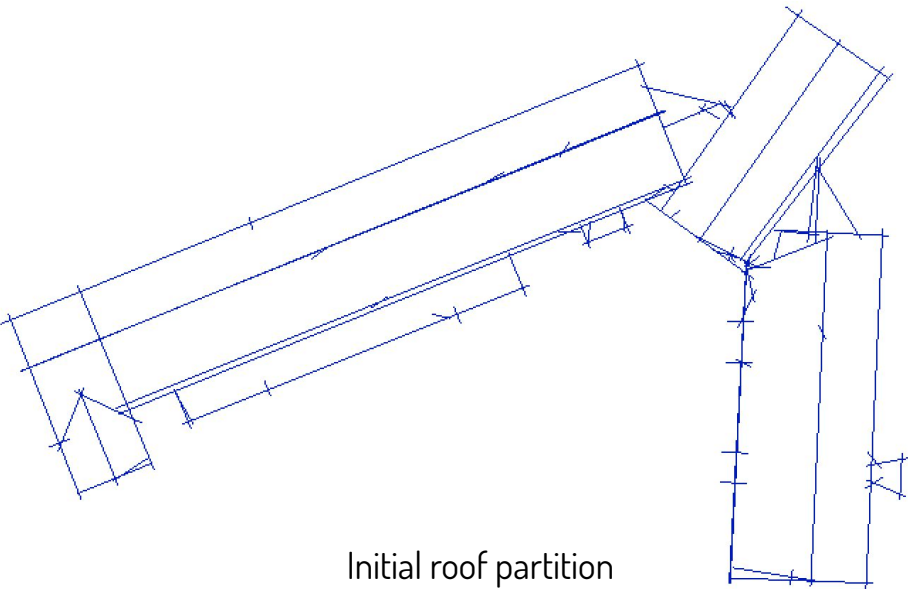
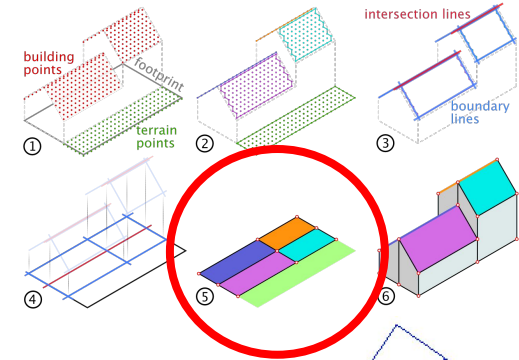
**Smoothness term:**

Edge length between adjacent faces with unequal plane label

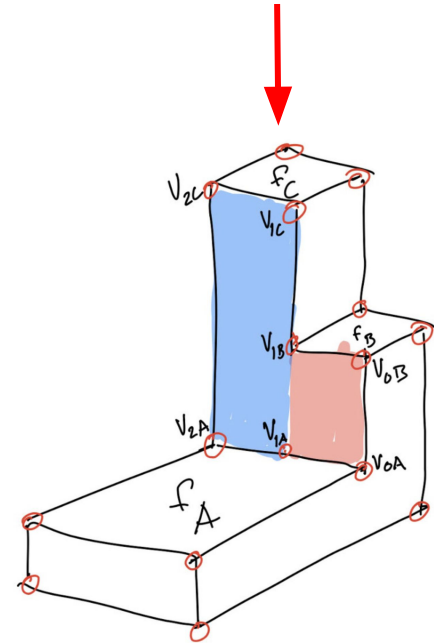
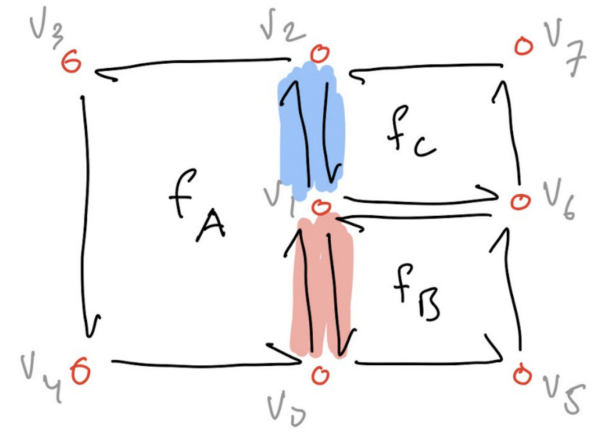
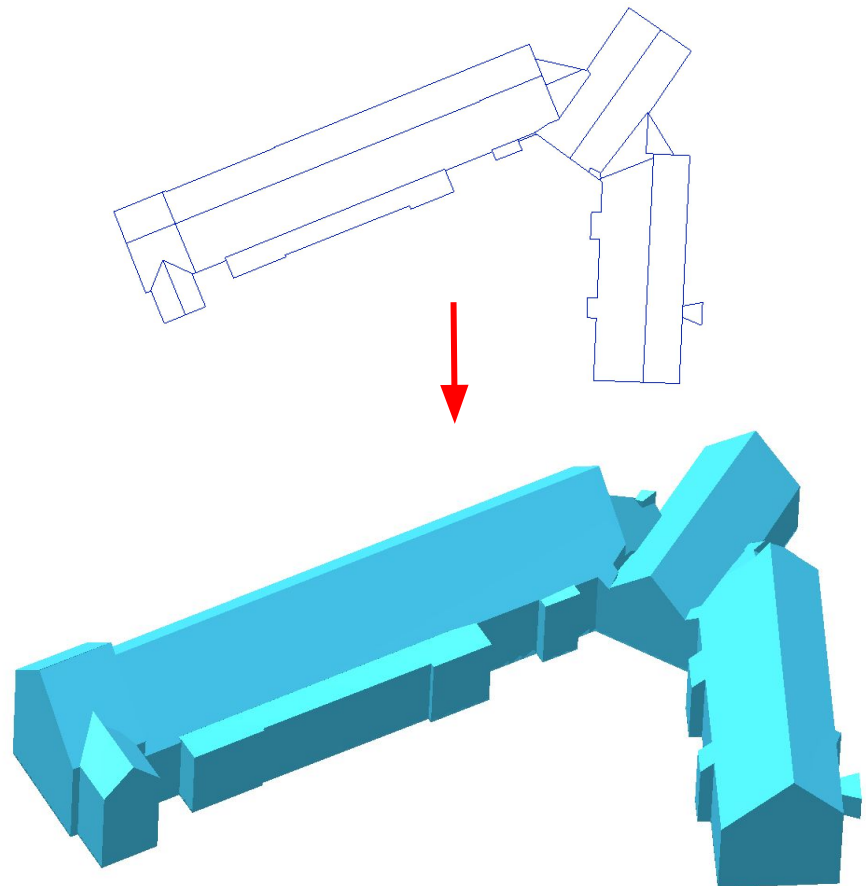
**Reduces complexity, discourages height discontinuities**



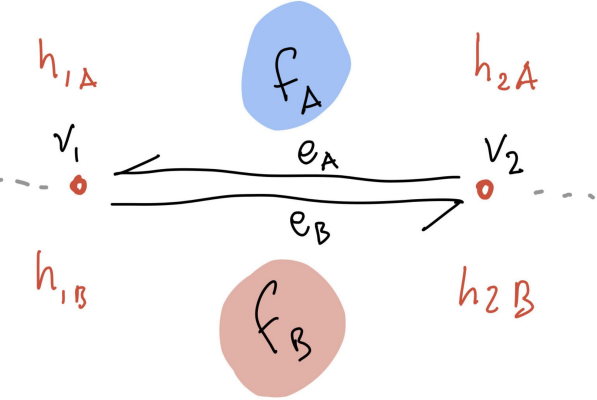
# Final roof partition



# Extrusion



# Extrusion



Case	condition	vertex order
	$h_{1A} < h_{1B}$ AND $h_{2A} < h_{2B}$	<ol style="list-style-type: none"> <li><math>v_{1B}, v_{1A}, v_{2A}, v_{2B}</math></li> </ol>
	$h_{1A} < h_{1B}$ AND $h_{2A} > h_{2B}$	<ol style="list-style-type: none"> <li><math>v_{1B}, v_{1A}, v_x</math></li> <li><math>v_{2A}, v_{2B}, v_x</math></li> </ol> } 2 Faces!
	$h_{1A} < h_{1B}$ AND $h_{2A} = h_{2B}$	<ol style="list-style-type: none"> <li><math>v_{1B}, v_{1A}, v_{2A}</math></li> </ol>

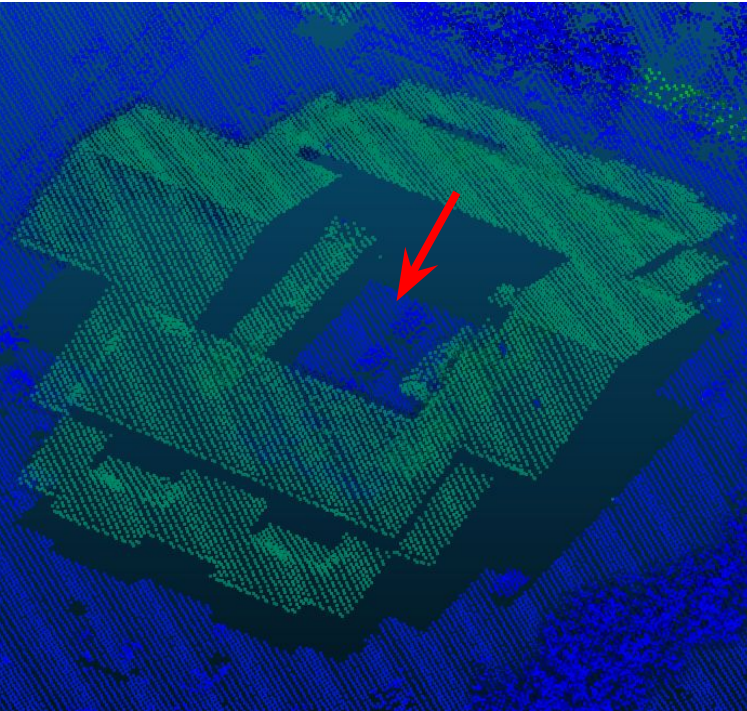
# Special cases



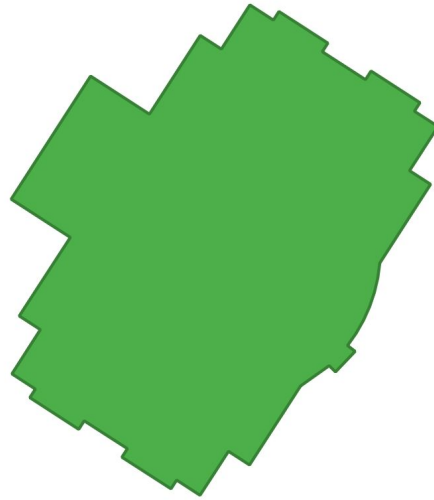
# Groundparts

In some cases BAG footprint includes groundparts

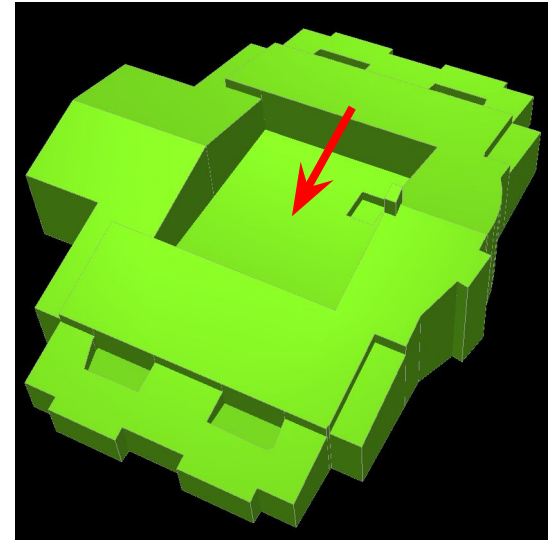
AHN3 ground and building class



BAG footprint



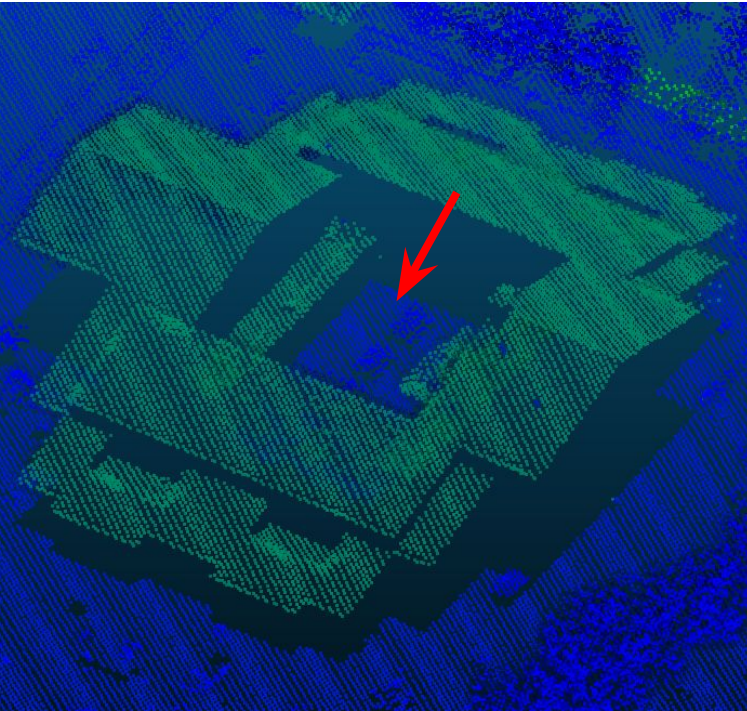
Reconstruction result:  
roofplane fitted to groundpart



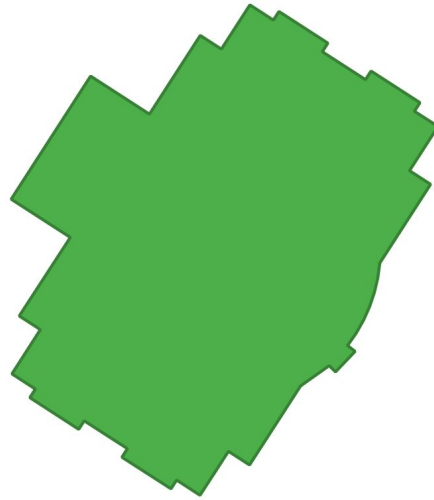
# Groundparts

Reconstruction with groundpart detection

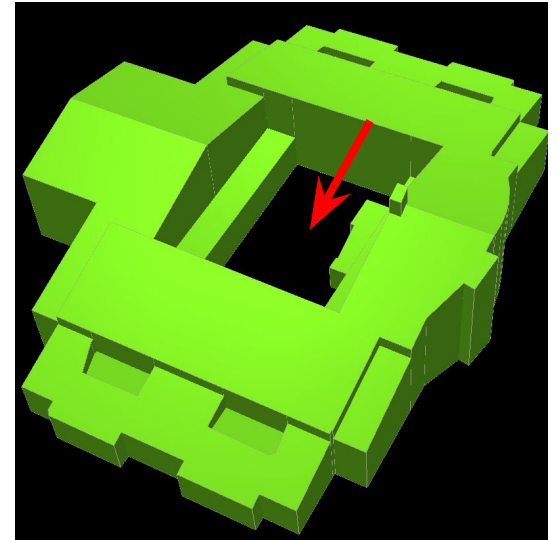
AHN3 ground and building class



BAG footprint

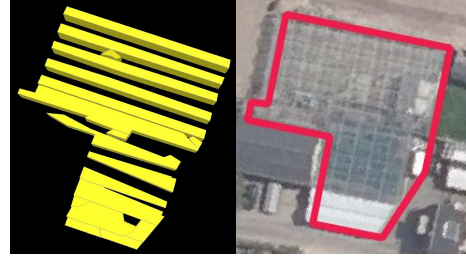


Reconstruction result:  
groundpart removed from output



# Limitation: glass roofs

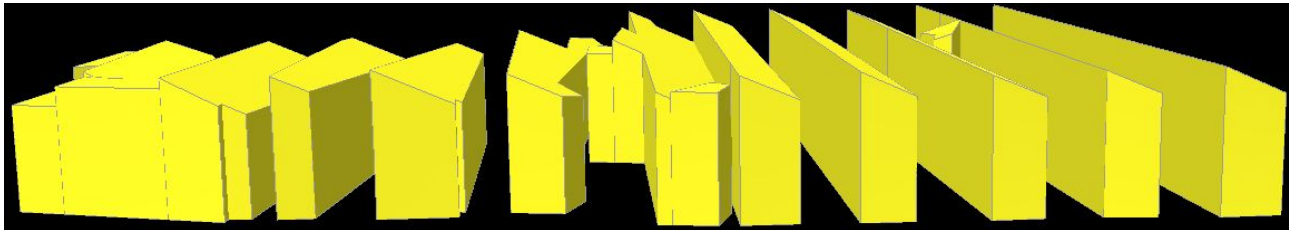
Green houses: both points on ground and on roof



AHN3  
ground and building class



Heightfield

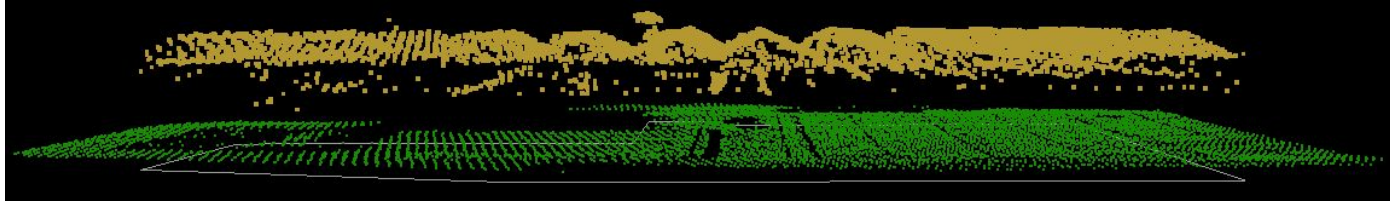


Reconstruction result

# Limitation: glass roofs

Green houses: both points on ground and on roof

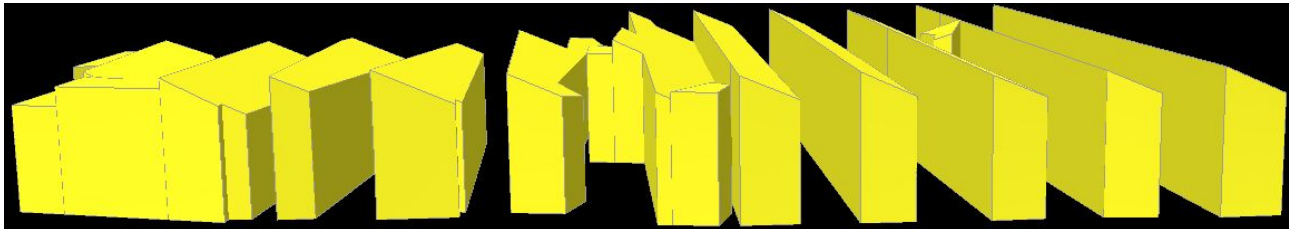
Current solution:  
Use greenhouse classification from  
TOP10NL, reconstruct as LoD 1.2



AHN3  
ground and building class

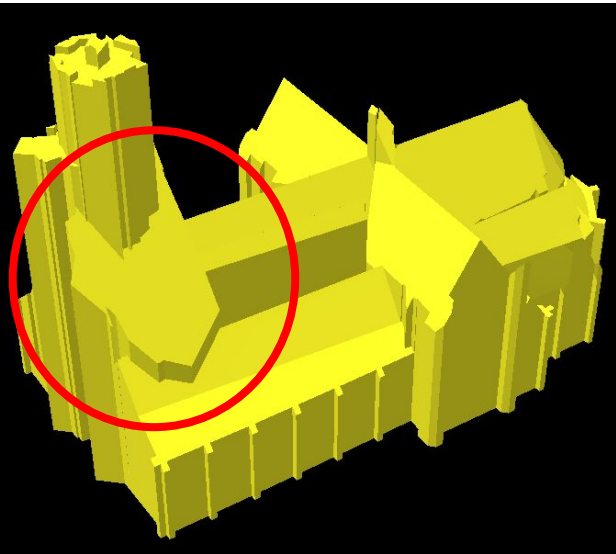


Heightfield

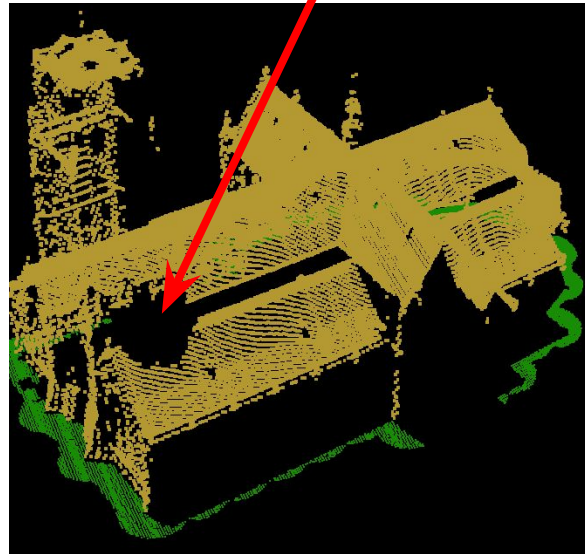


Reconstruction result

# Limitations: occlusion/no-data



Reconstruction

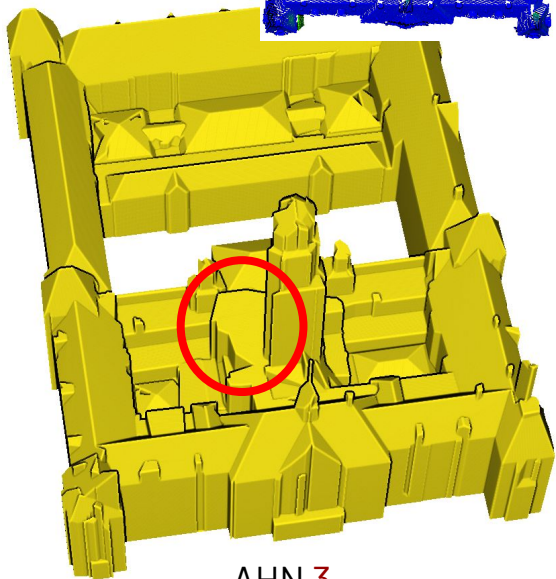
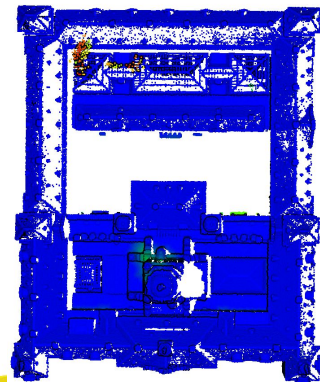
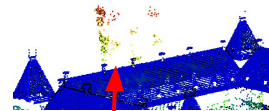
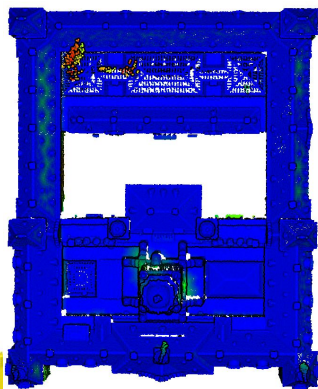
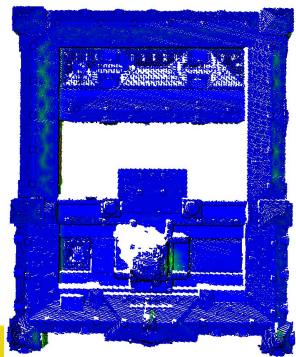


AHN3 ground and building class

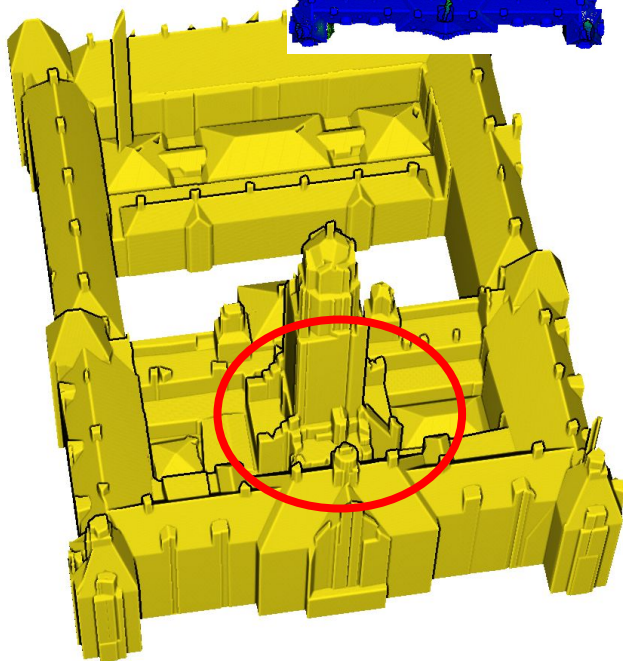


Heightfield

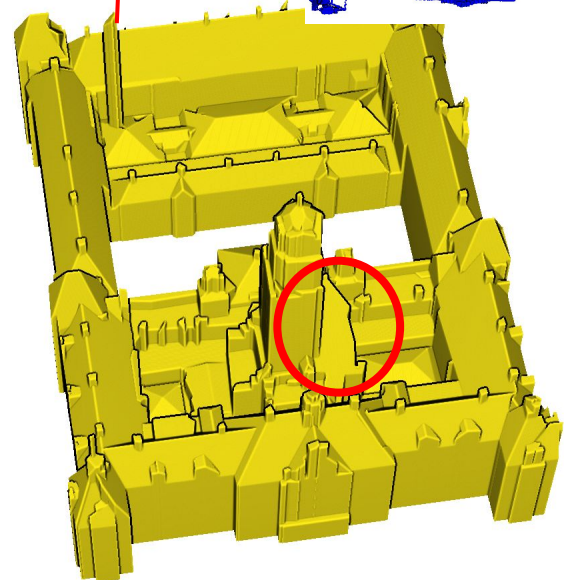
# Fuse two point clouds



AHN 3



AHN 3+4



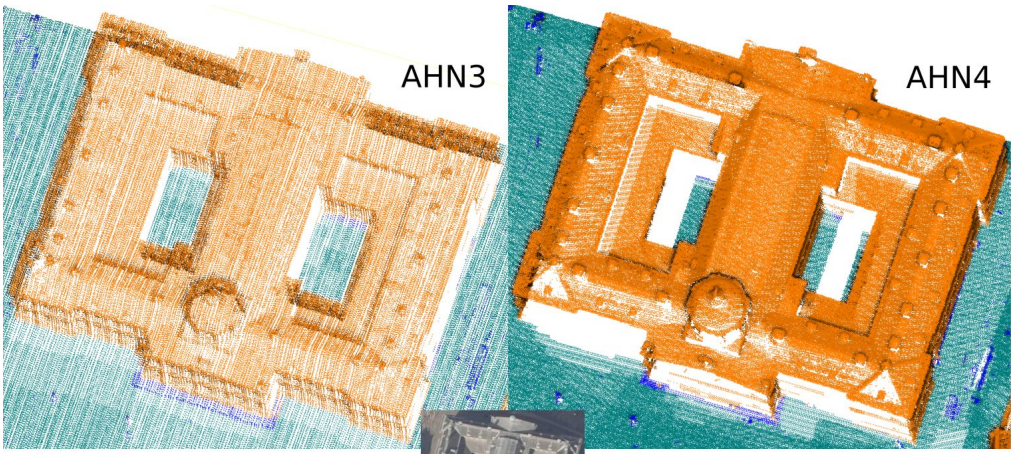
AHN 4

# Spherical surfaces

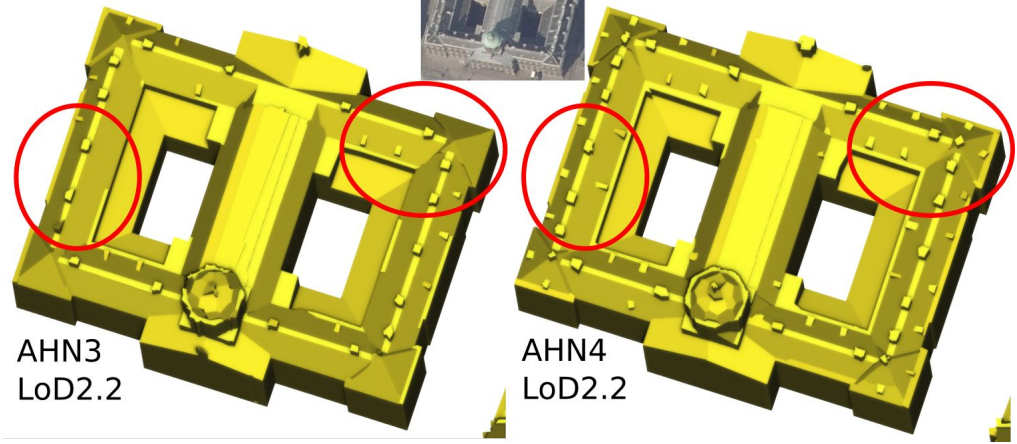
Are approximated with planar surfaces if sufficient point density



# Effect of point density input point cloud

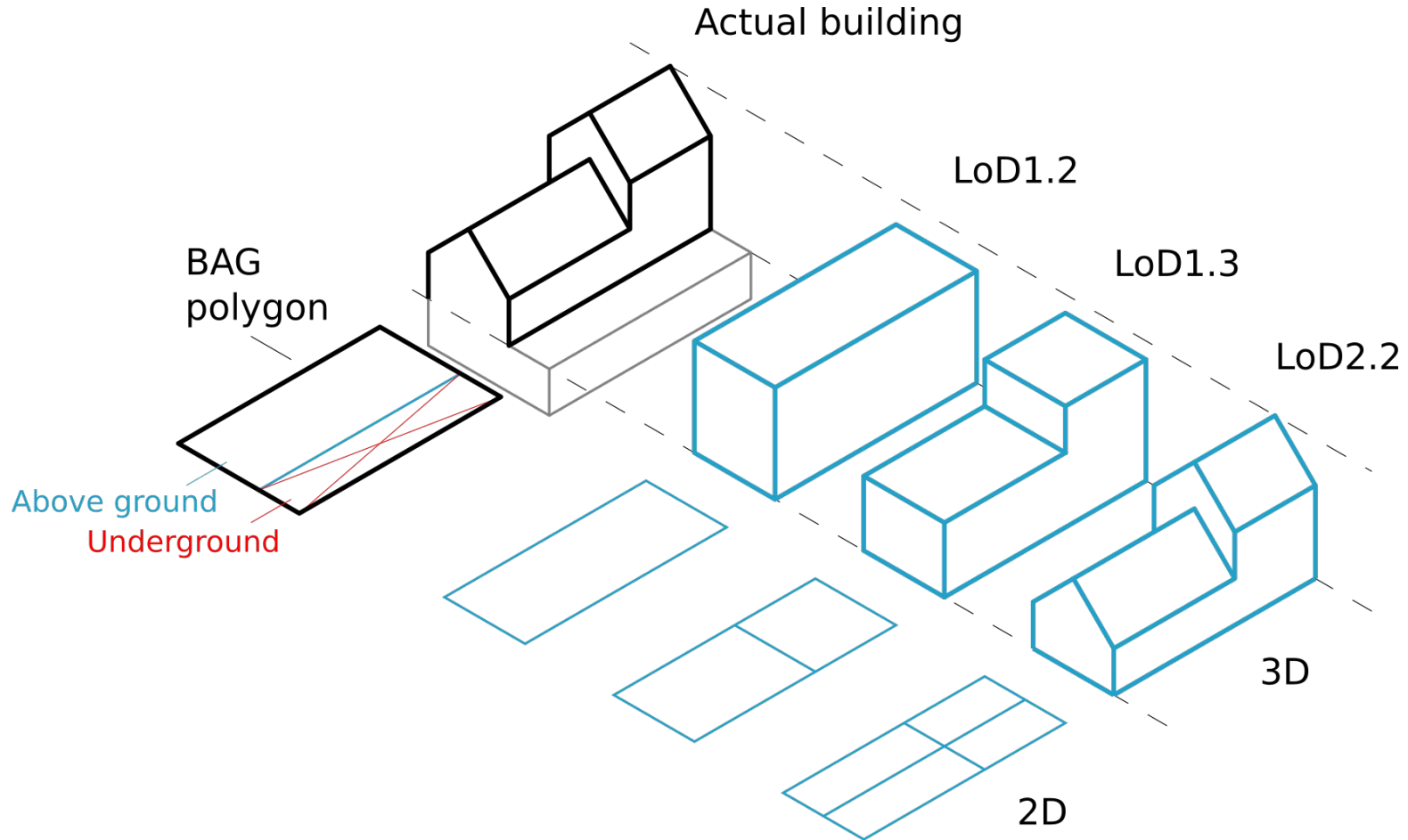


~2x point density



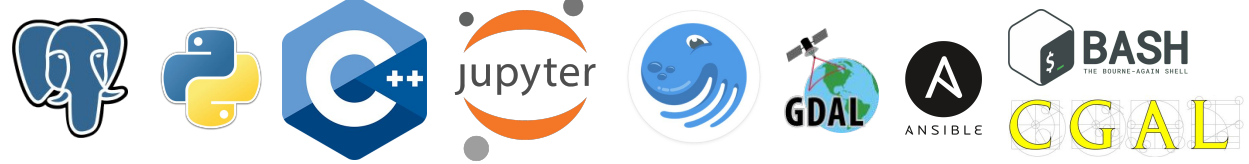


# 3D BAG layers: 3 LoDs

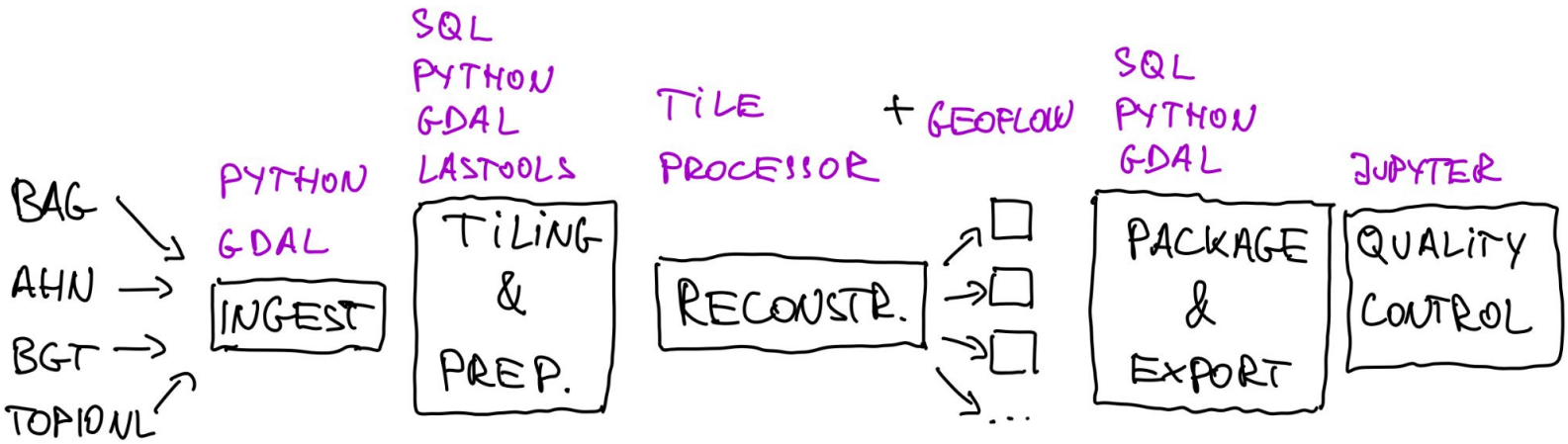


# Data management

# Architecture



## DAGSTER

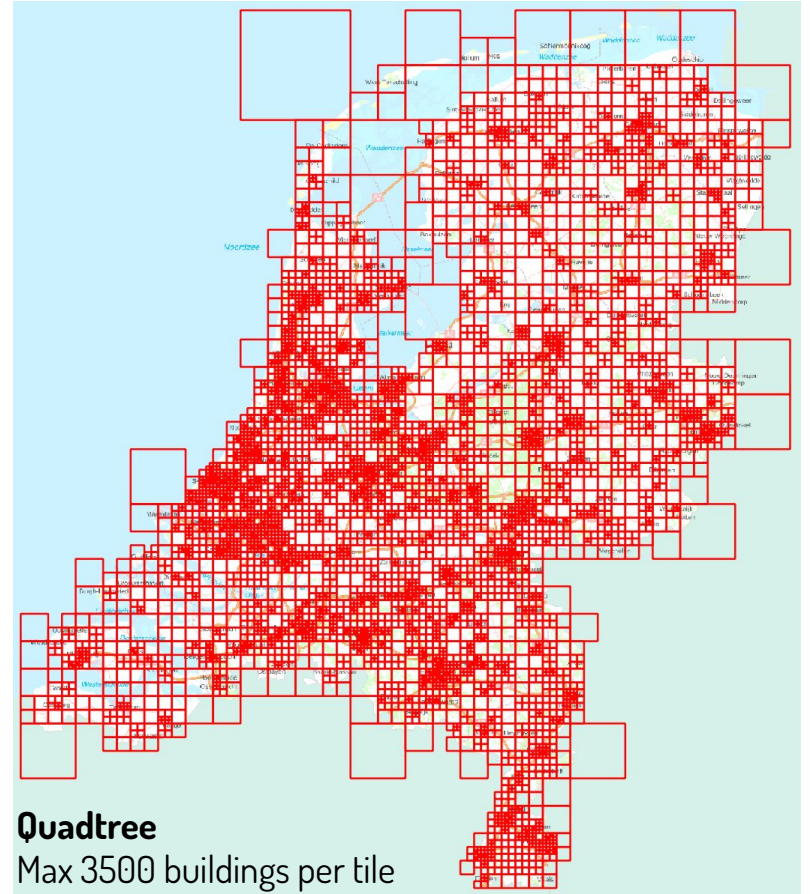
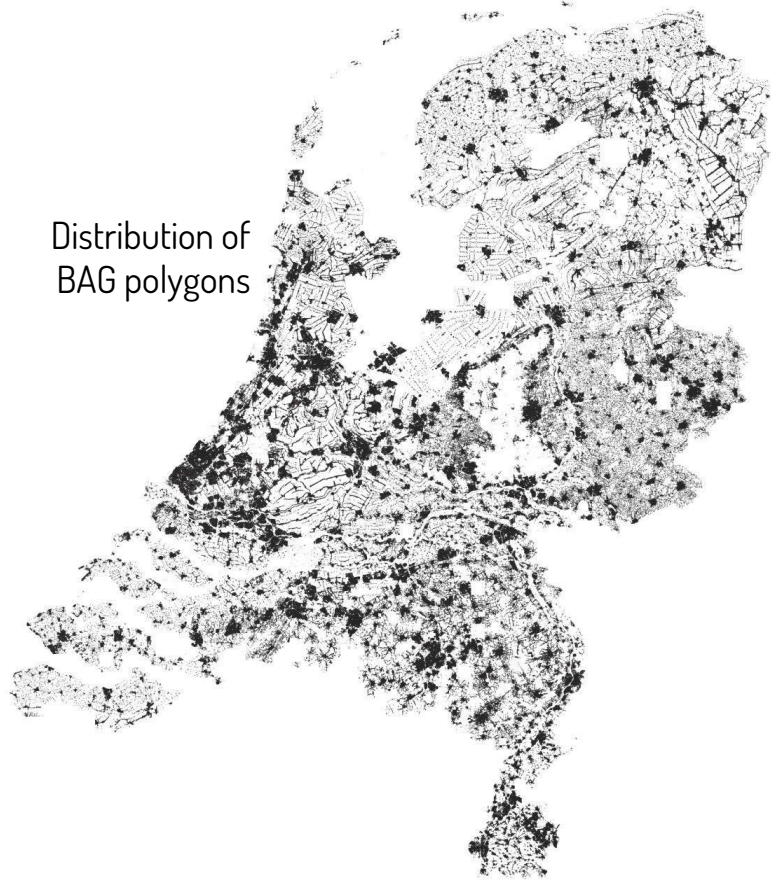


## POSTGRESQL

## FILESYSTEM

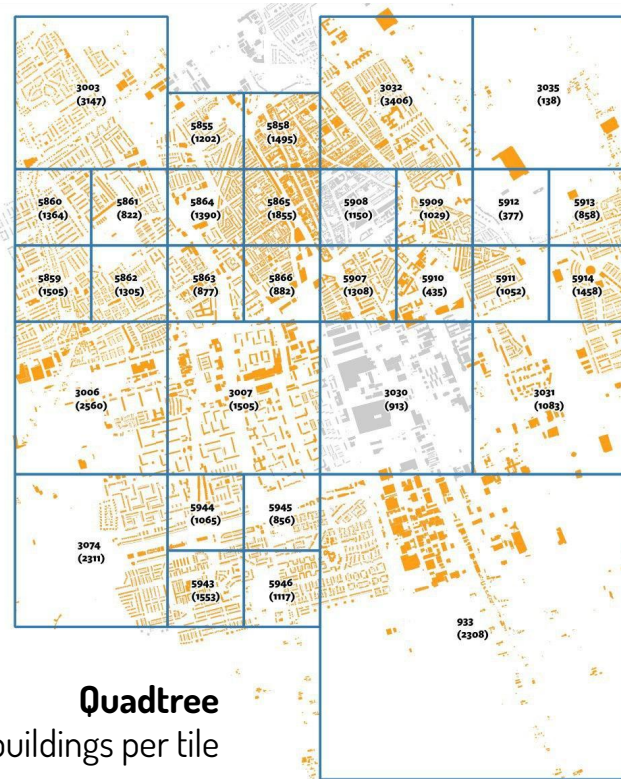
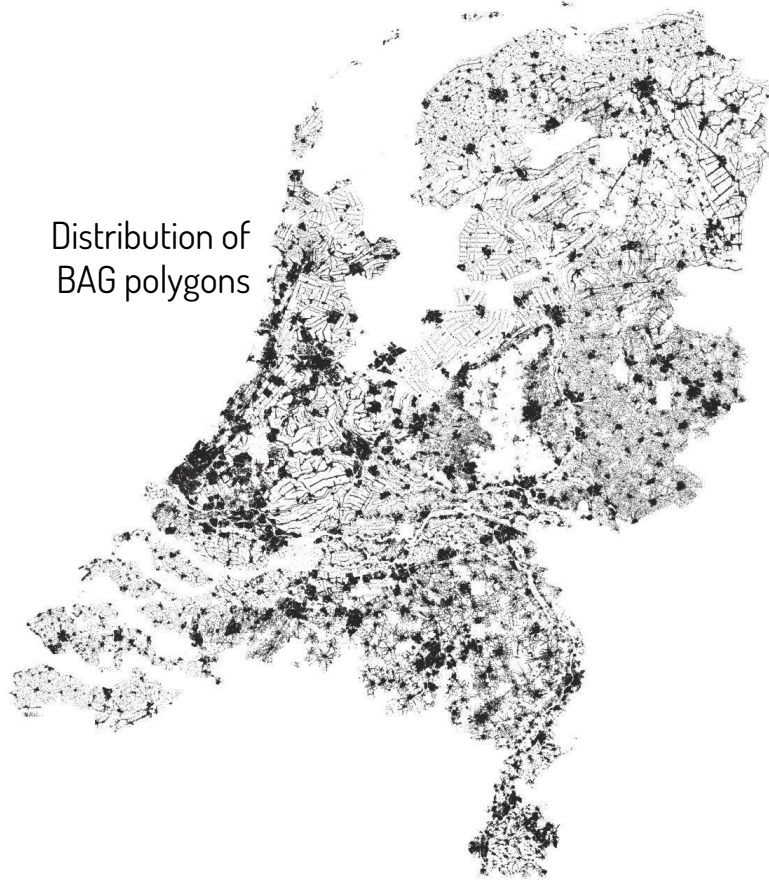
# How to tile the data?

Distribution of  
BAG polygons



# How to tile the data?

Distribution of BAG polygons



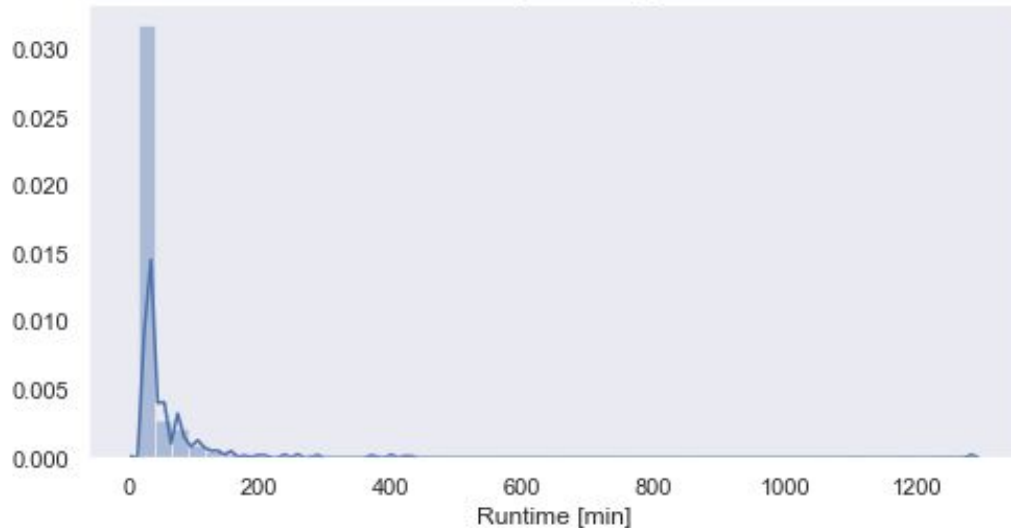
**Quadtree**

Max 3500 buildings per tile

# Stats for nerds; reconstruction time

- **Buildings:** 8.138 quadtree tiles, 10 226 585 buildings total
- **Point cloud:** 907 323 square tiles of 200x200 meters, ~600B points total
- ~45 hours on 20 CPU's (2x 2014 Intel Xeon CPU E5-2650 v3 @ 2.30GHz)

Runtime of longest running 5% tiles

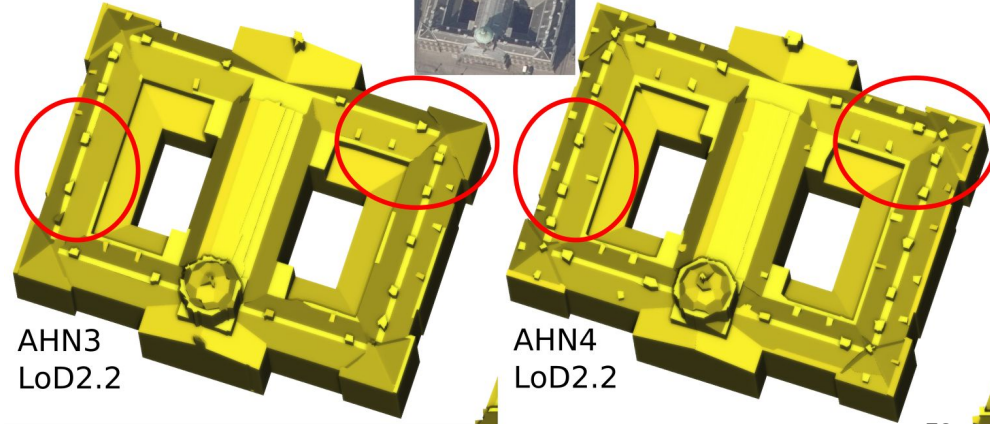
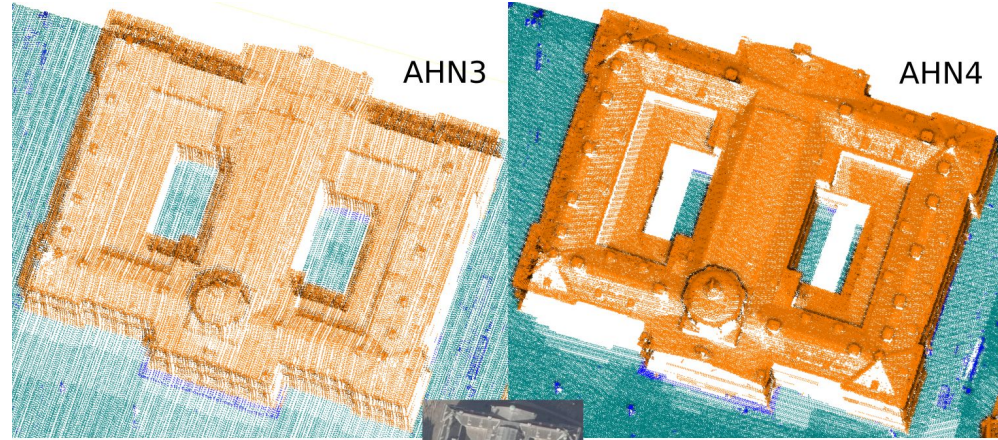


Reconstruction time **per building**,  
for all LoD-s,  
excl. I/O,  
milliseconds

Min.	:	1
1st Qu.	:	28
Median	:	46
Mean	:	190
3rd Qu.	:	76

# What's next?

- Planned:
  - Polish and open source reconstruction algorithm
  - Further improve data quality
  - more detailed, up-to-date point clouds
  - versioning
  - 3D web API
  - ...



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



3D geoinformation

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