3D BAG

GEO1004:

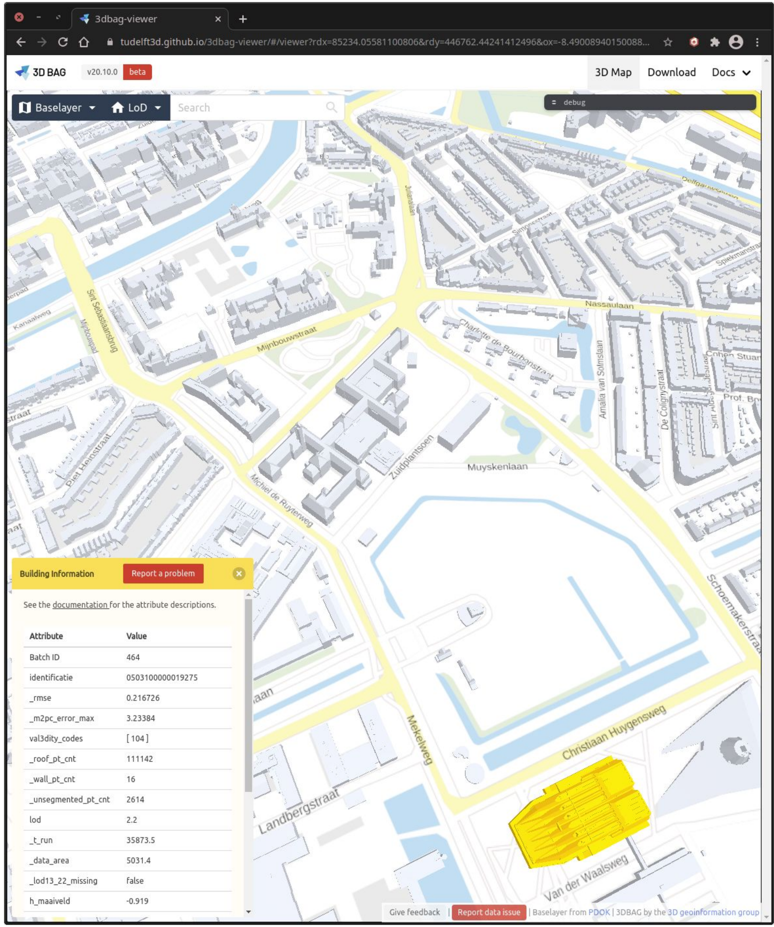
3D modelling of the built environment

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

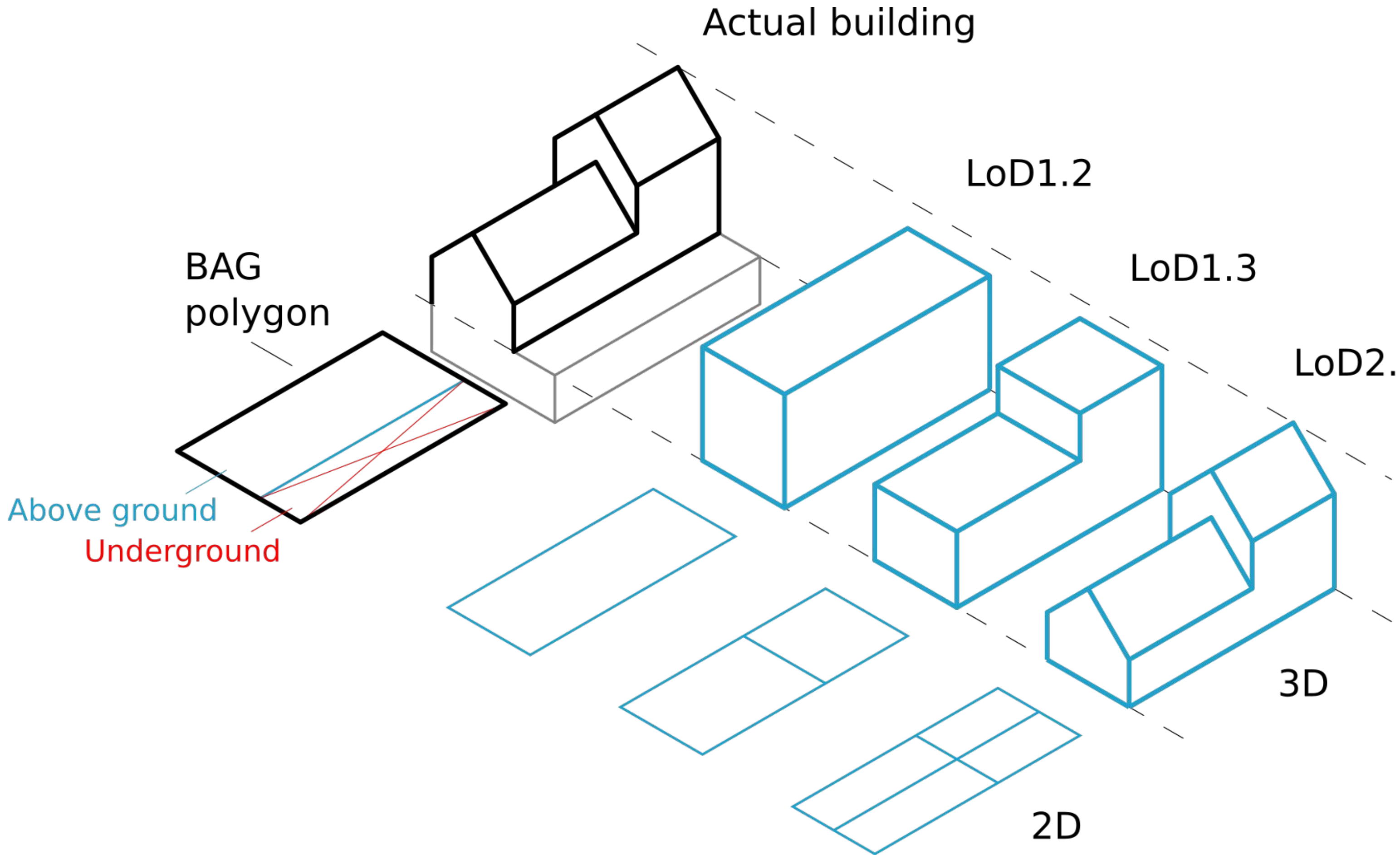
3D geoinformation
Department of Urbanism
Faculty of Architecture and the Built Environment
Delft University of Technology

What is 3D BAG (v2)?

- 3D building models for all ~10M buildings in NL
- In LoD: 1.2, 1.3, 2.2
- Fully automatically generated
- Based on the 'official' BAG data and national AHN point cloud and some more
- Open data
- Dissemination platform with 3D webviewer



3D BAG layers: 3 LoDs



Viewer demo

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

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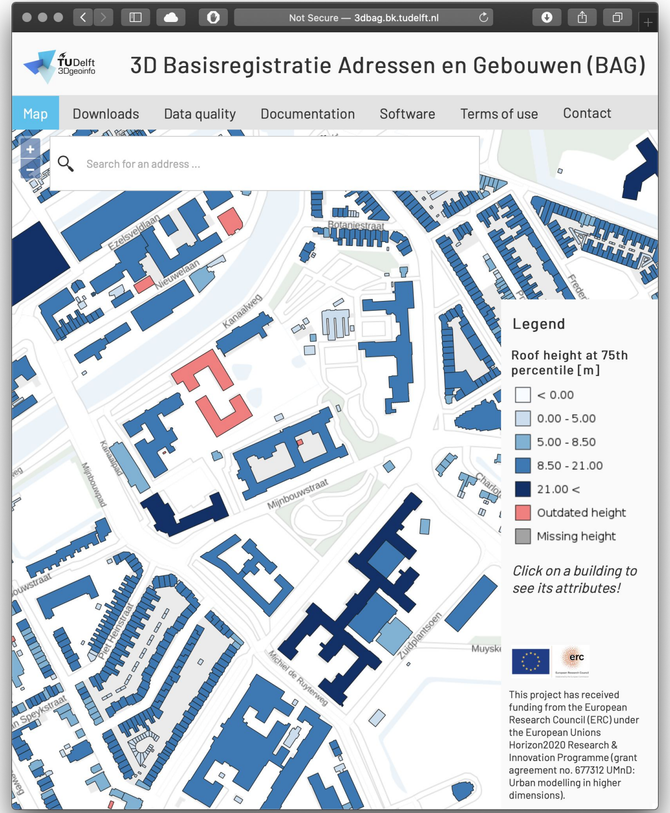
Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

Rijksinstituut voor Volksgezondheid en Milieu
Ministerie van Volksgezondheid, Welzijn en Sport

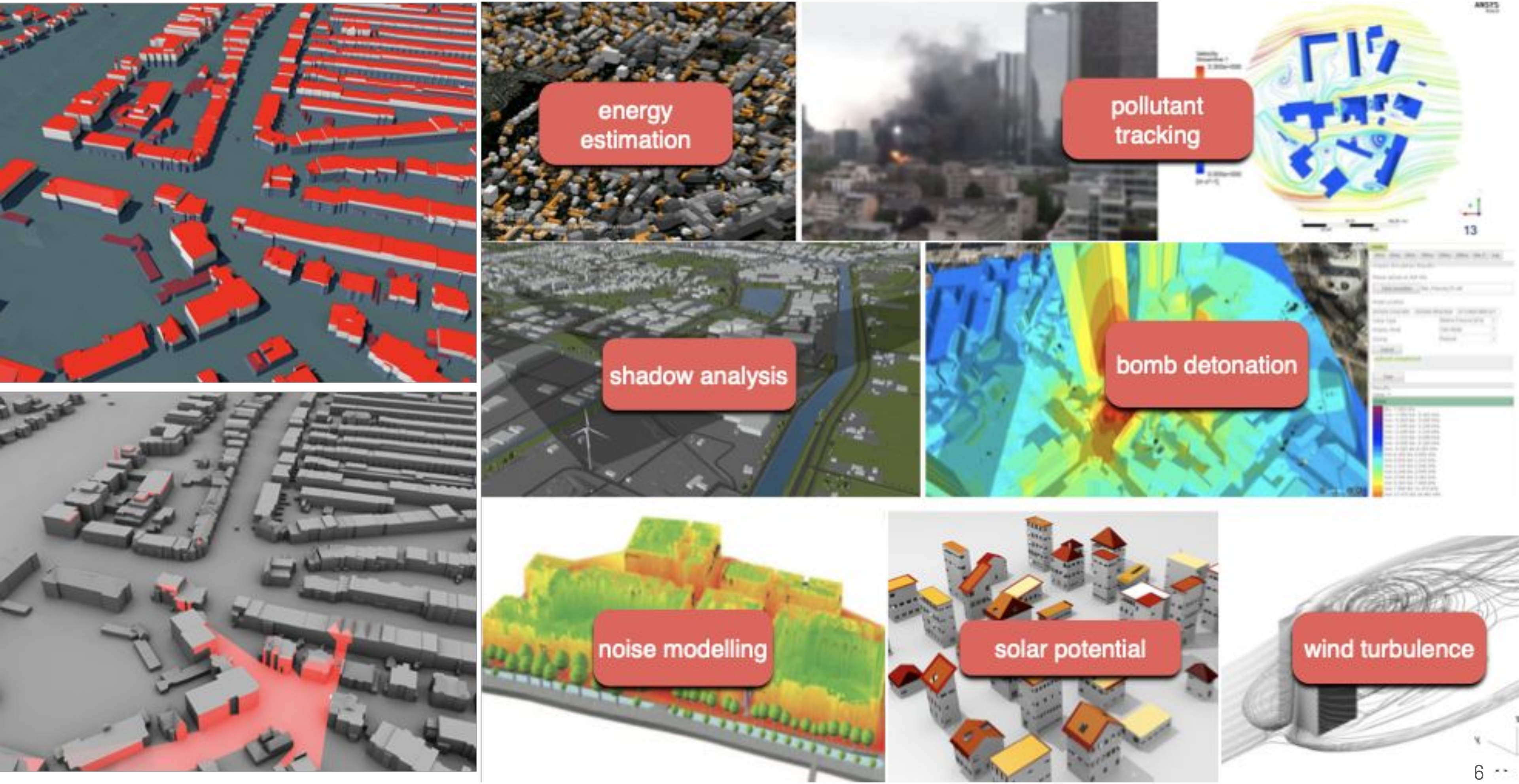
kadaster

Interprovinciaal Overleg
van en voor provincies

erc
European Research Council
Established by the European Commission



3DBAG v1


energy estimation
pollutant tracking
shadow analysis
bomb detonation
noise modelling
solar potential
wind turbulence

Overview

1. Process overview
2. Building reconstruction
3. Data management

Process overview

Process

BAG
Buildings (Pand)

TOP10NL
Buildings (Gebouw)

BGT
Buildings (Pand)
Roads (Wegdeel)

AHN3
Building alpha shapes
Acquisition dates

Point cloud (LAZ)

Greenhouse / Warehouse

Underground / Floating

Timeliness

Excl. FOOTPRINTS

In. FOOTPRINTS

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re-tiling

5x6 km → 200x200 m

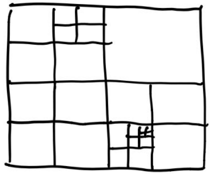
Excl. FOOTPRINTS

In. FOOTPRINTS

POINT CLOUD

Process

adaptive tiling
max. 3500 footprint



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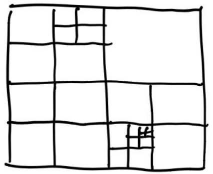

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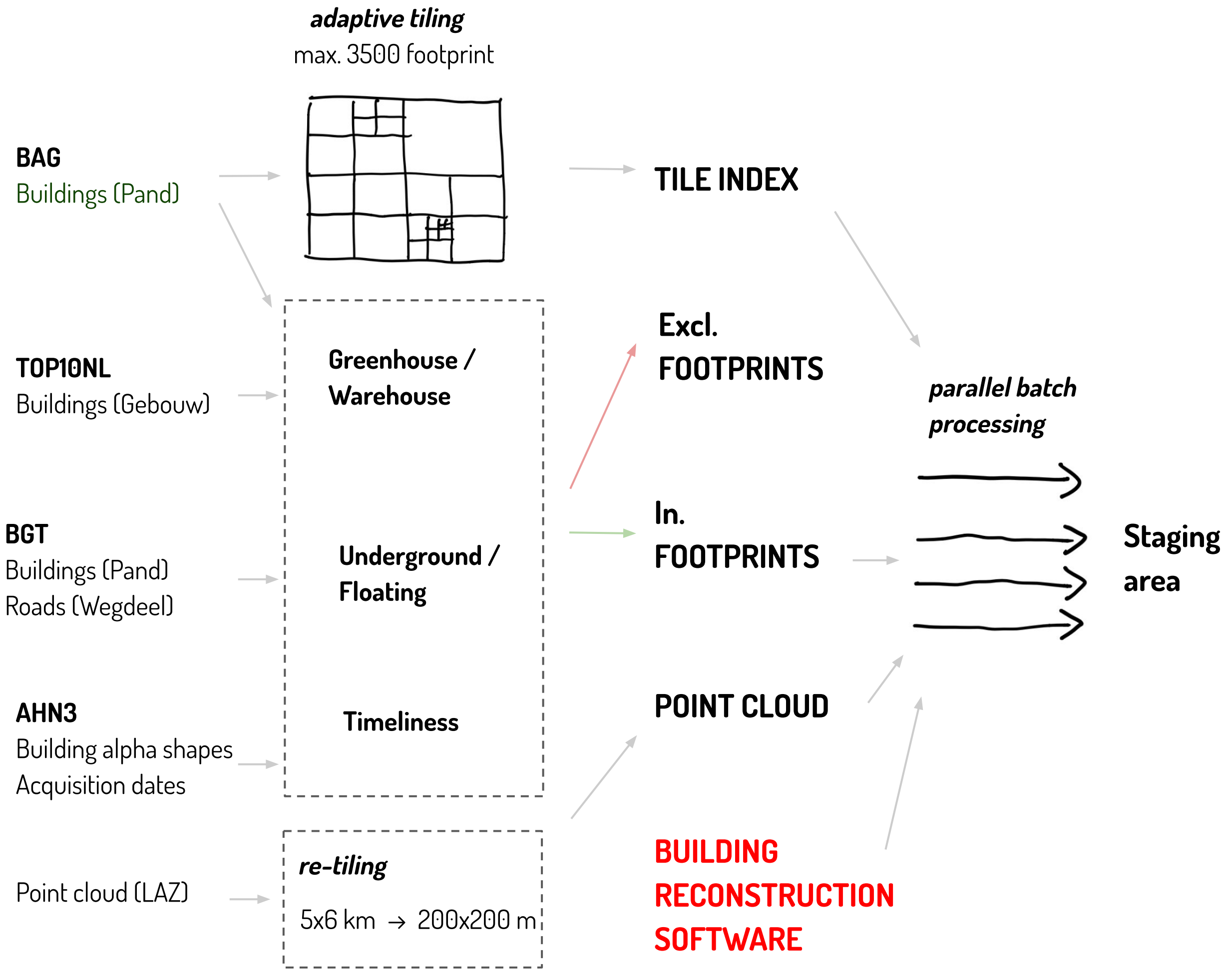
BUILDING RECONSTRUCTION SOFTWARE

Process



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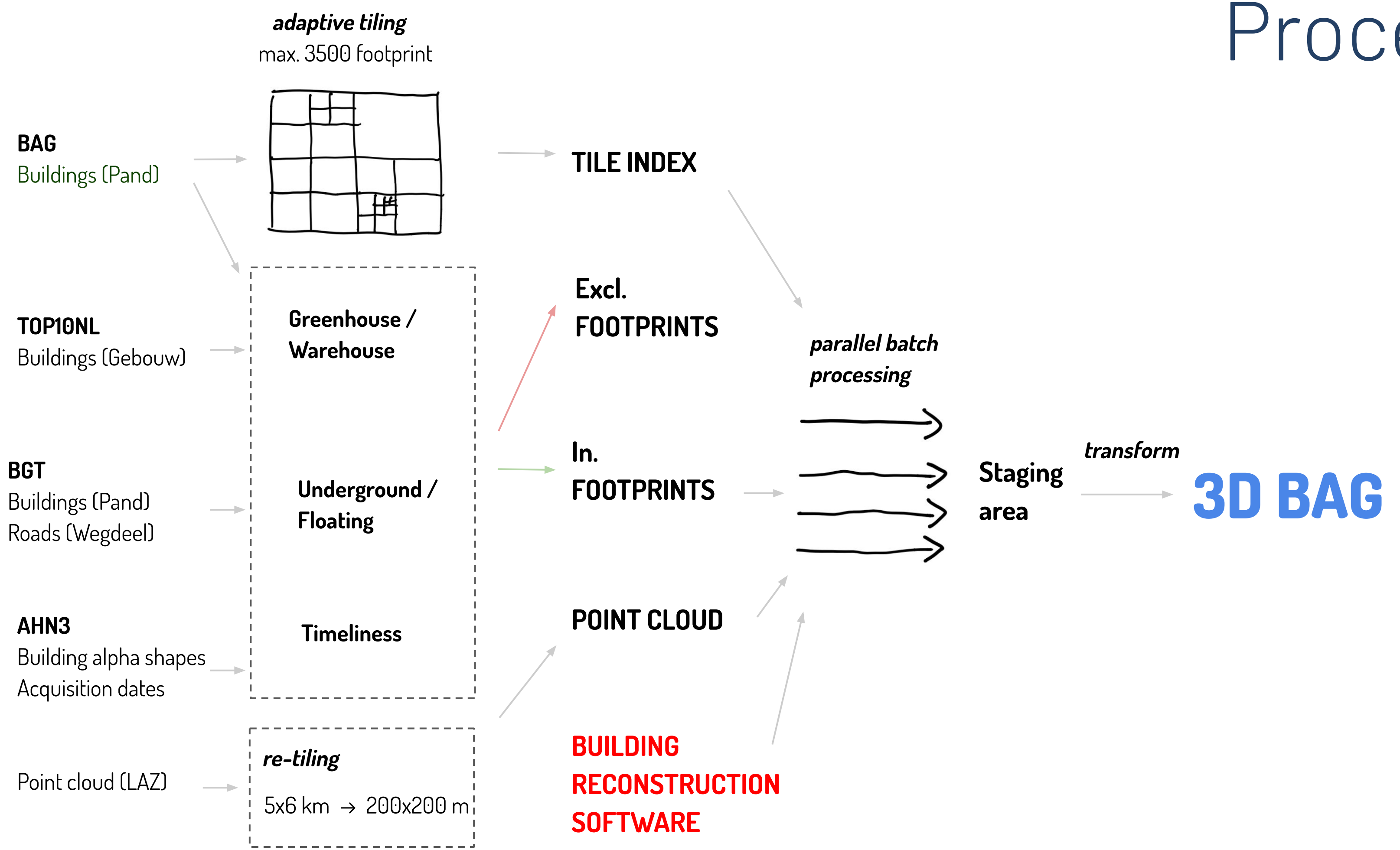
Excl. FOOTPRINTS
In. FOOTPRINTS
POINT CLOUD
BUILDING RECONSTRUCTION SOFTWARE
parallel batch processing
Staging area

Process



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Excl. FOOTPRINTS
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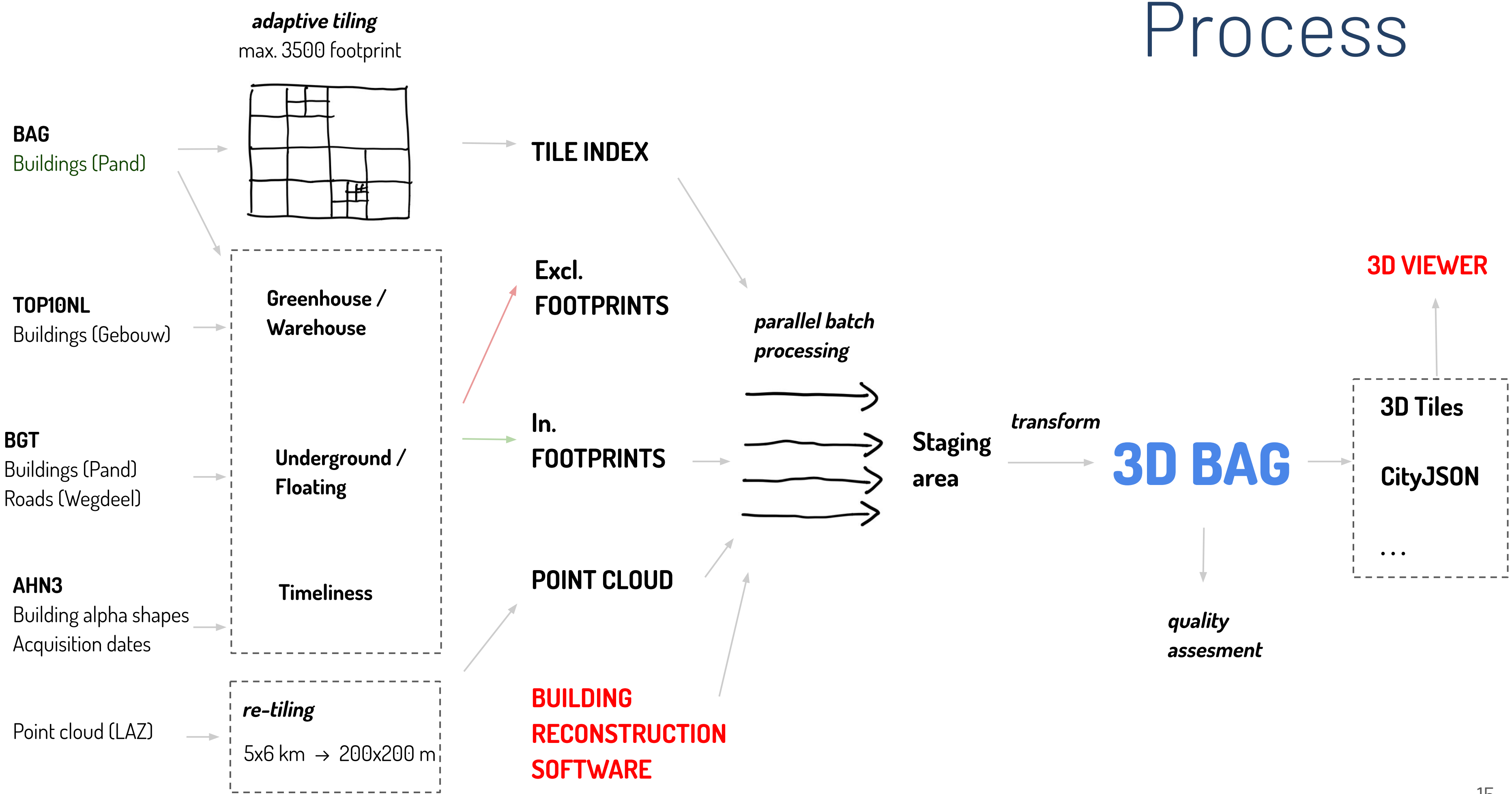
POINT CLOUD
BUILDING RECONSTRUCTION SOFTWARE
parallel batch processing
Staging area
transform
3D BAG

Process



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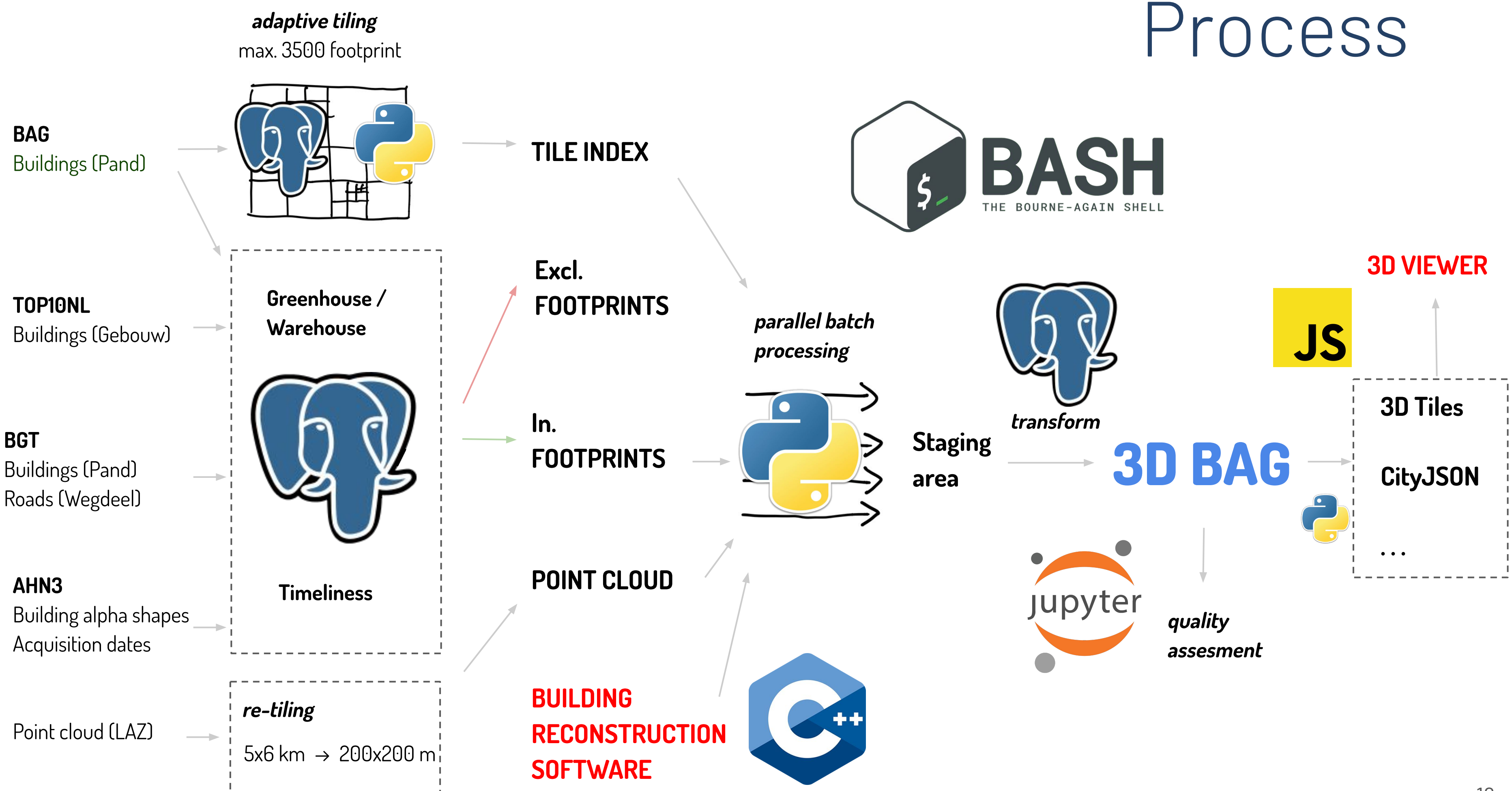
POINT CLOUD
BUILDING
RECONSTRUCTION
SOFTWARE
parallel batch
processing
Staging
area
transform
3D BAG
quality
assesment
3D VIEWER
3D Tiles
CityJSON
...

Process



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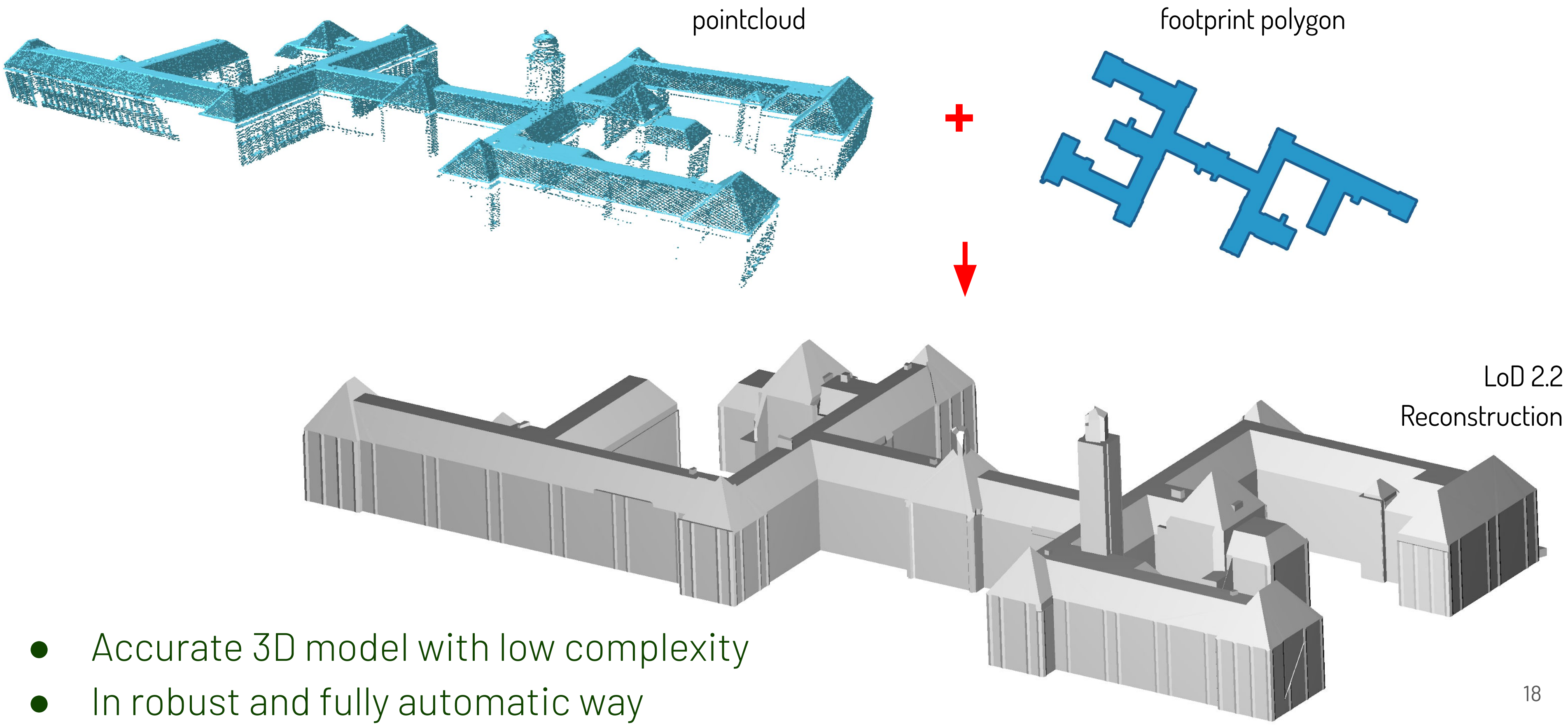
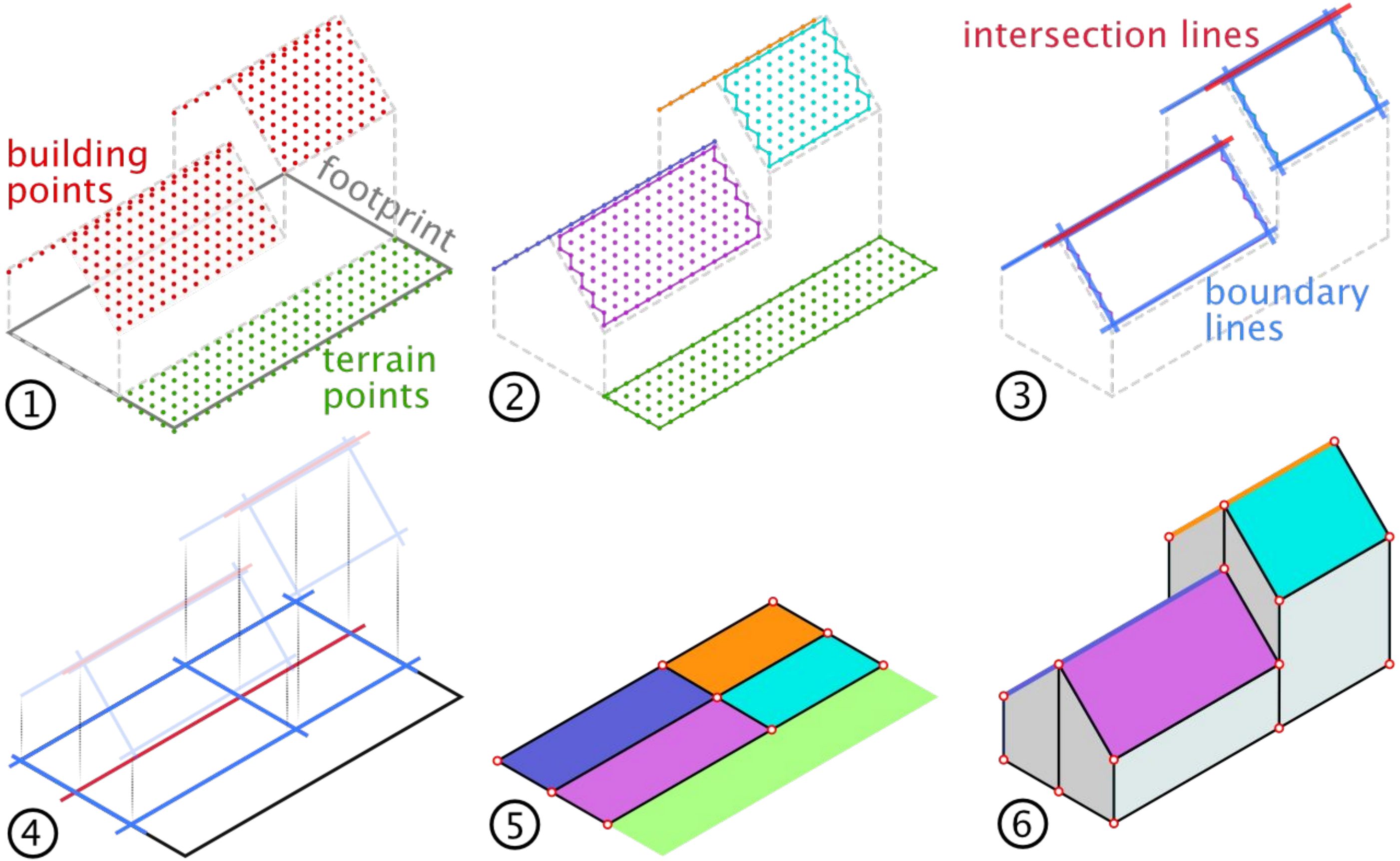
Building reconstruction

Building reconstruction

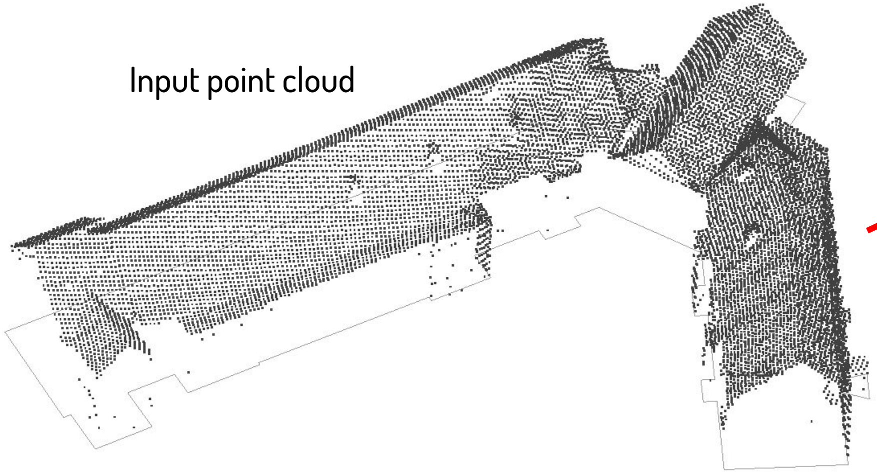


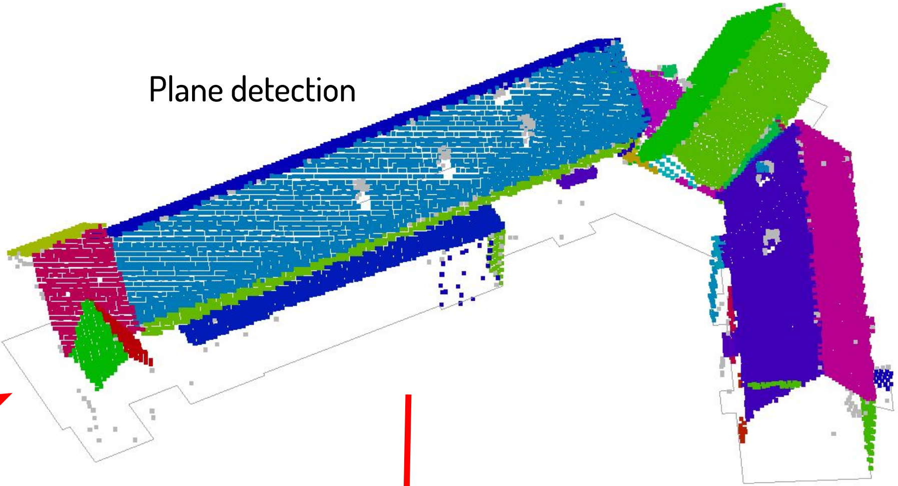
- Accurate 3D model with low complexity
- In robust and fully automatic way

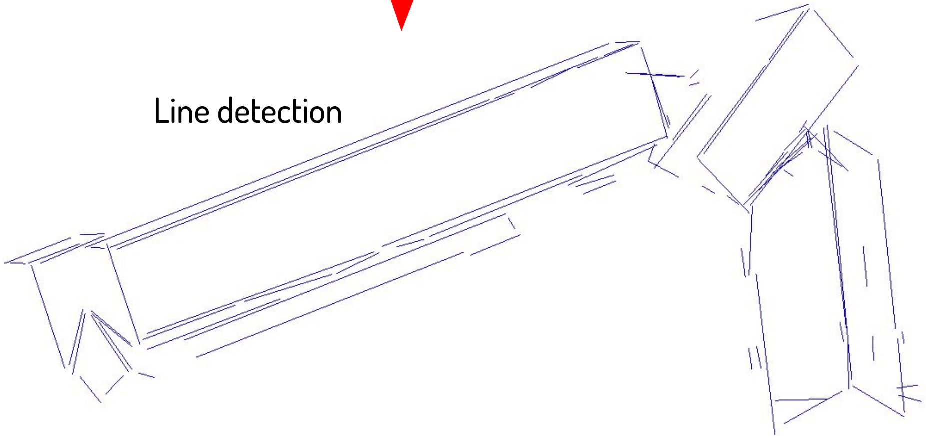
Overview building reconstruction method



Feature extraction

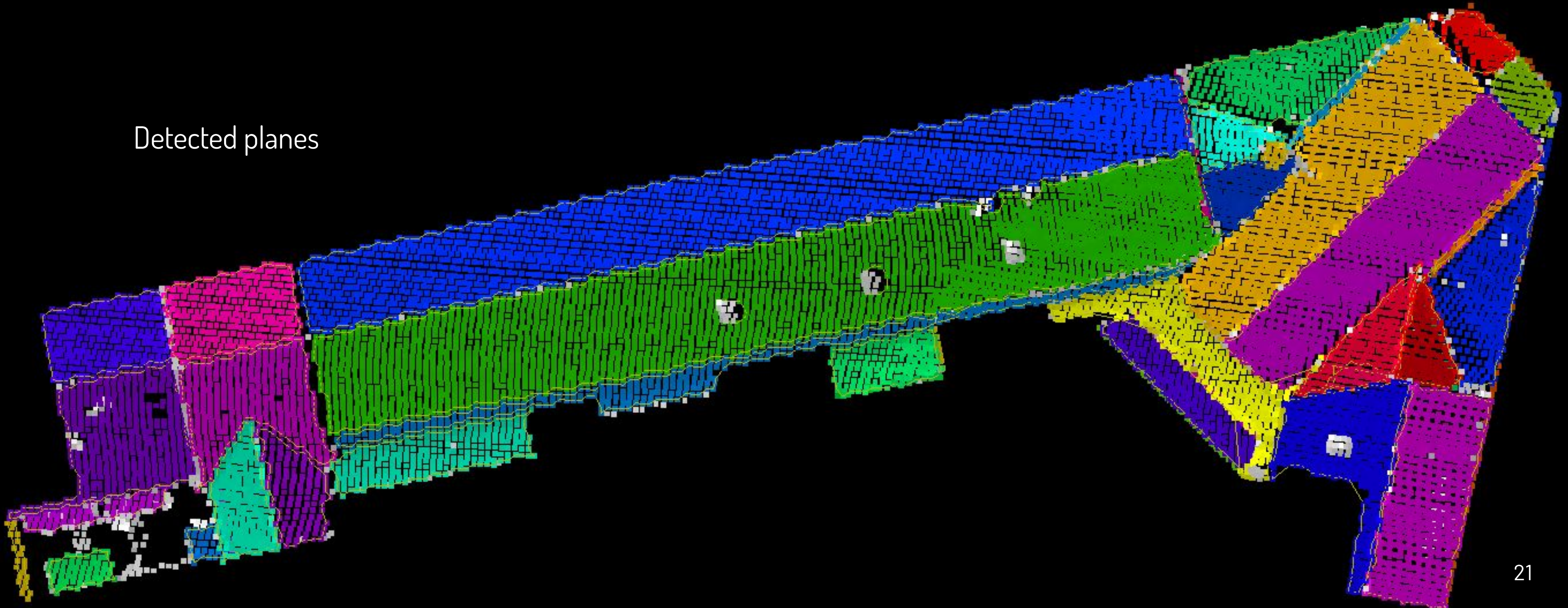






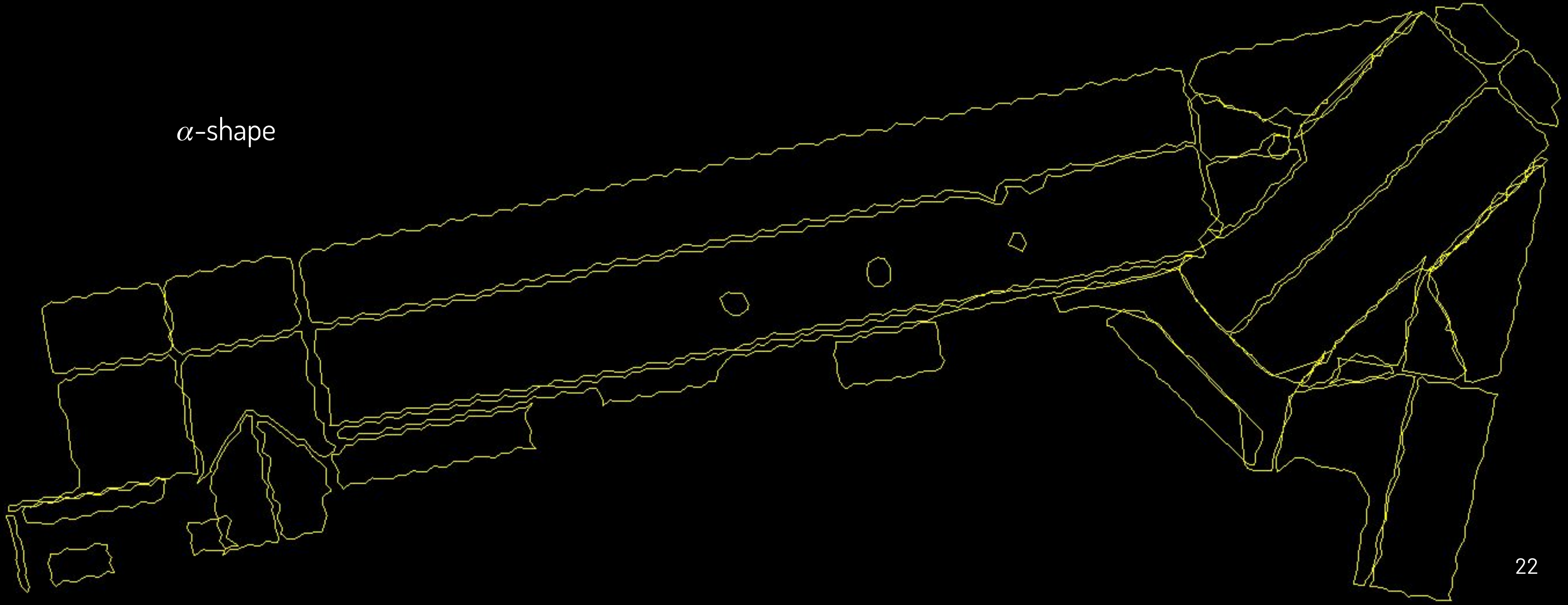
Feature extraction

Detected planes



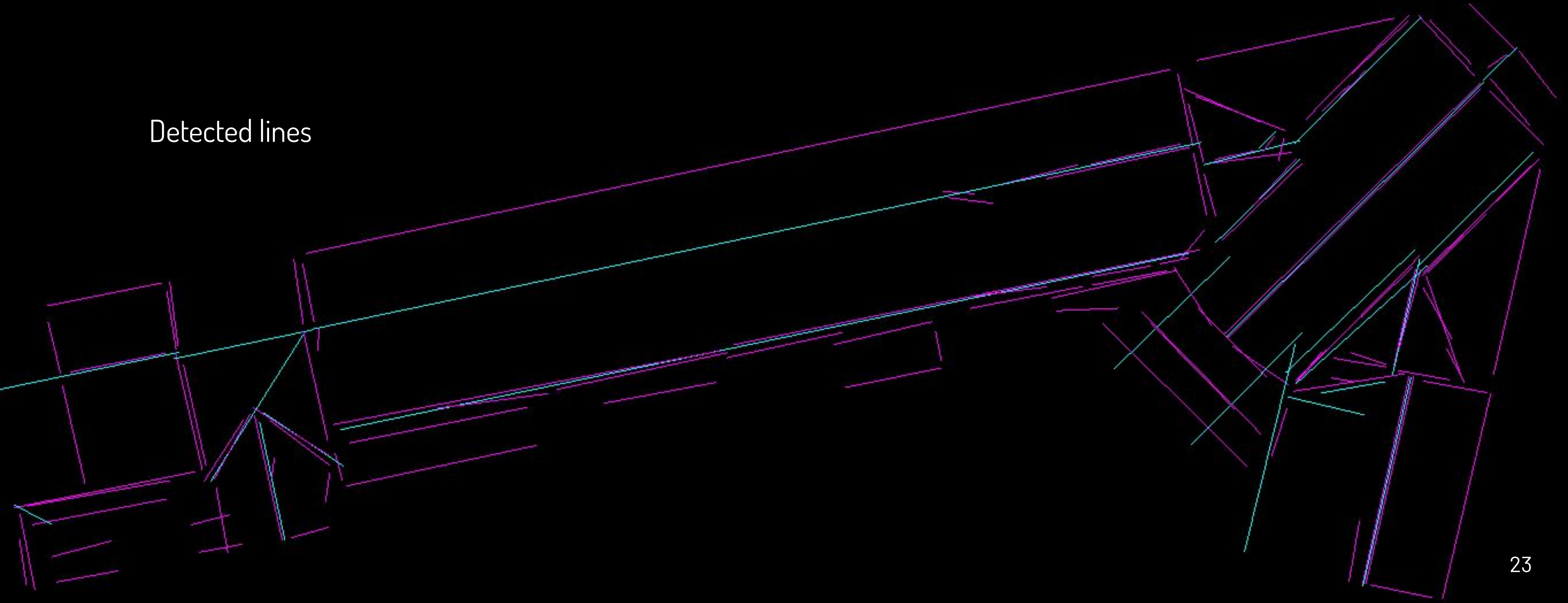
Feature extraction

α-shape



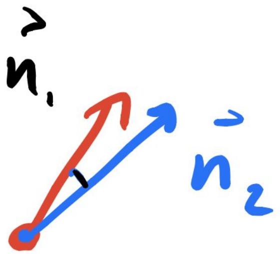
Feature extraction

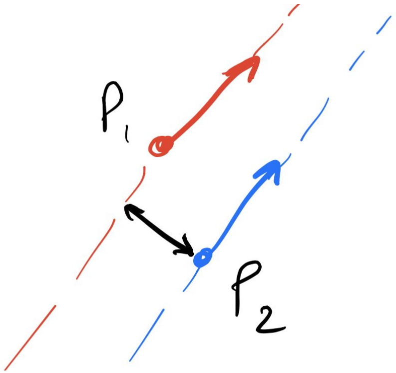
Detected lines



Line regularisation

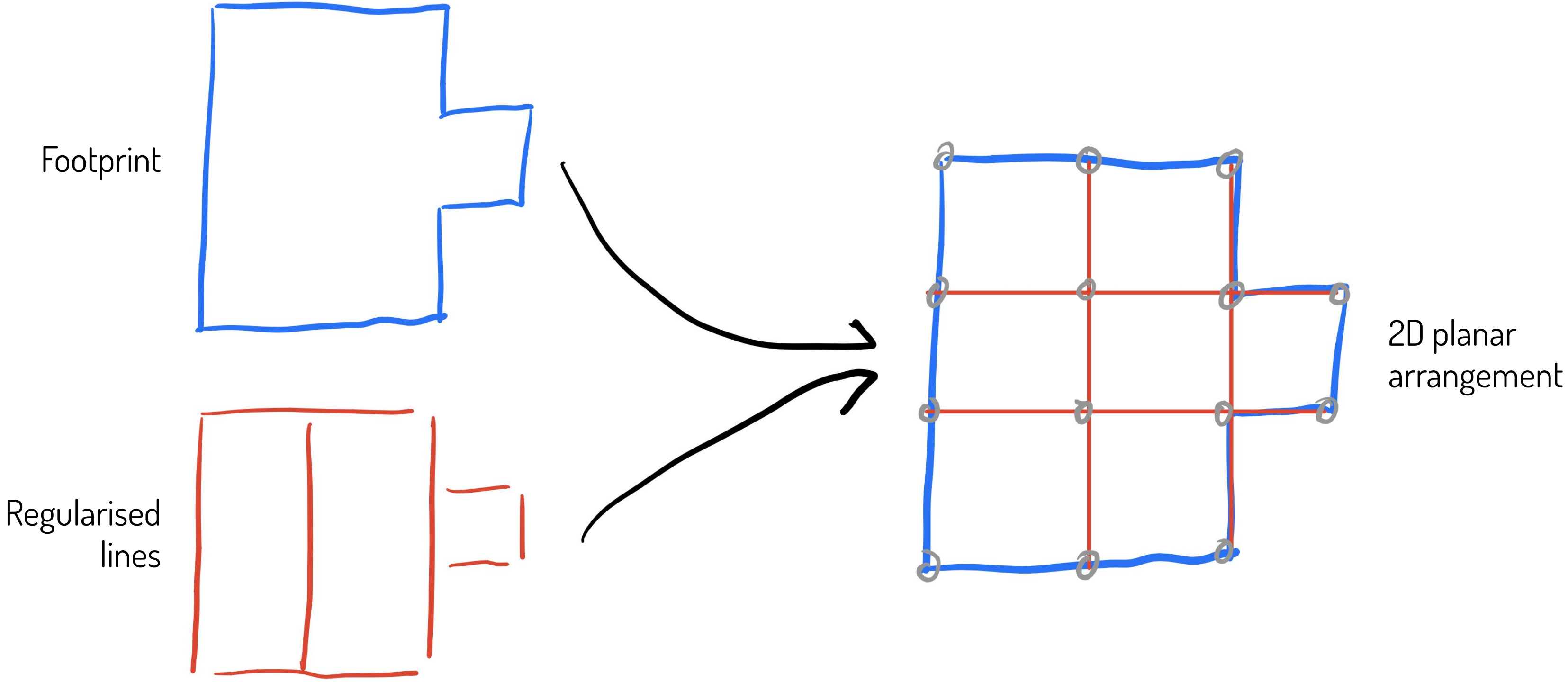
1. Cluster lines by angle
2. Cluster lines by distance
3. Keep one line per cluster





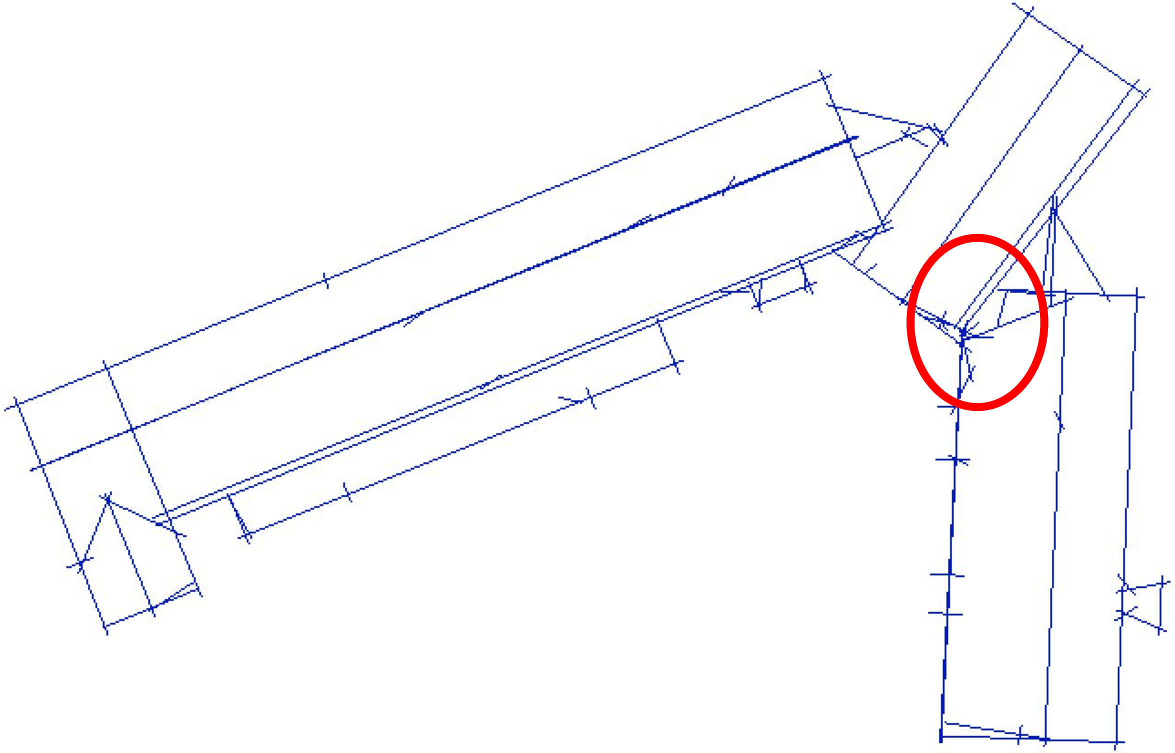
Initial roof partition

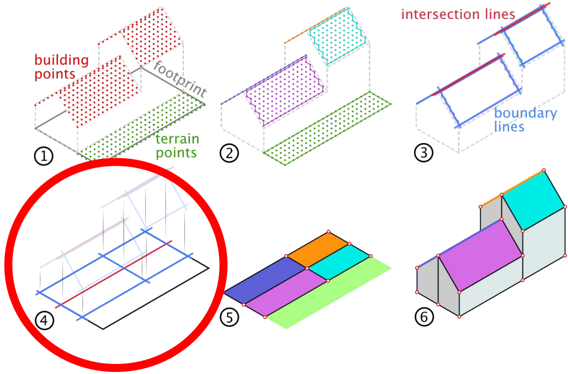
Using fully topological data-structure (DCEL). With CGAL 2D arrangement package



Initial roof partition

Still many small faces



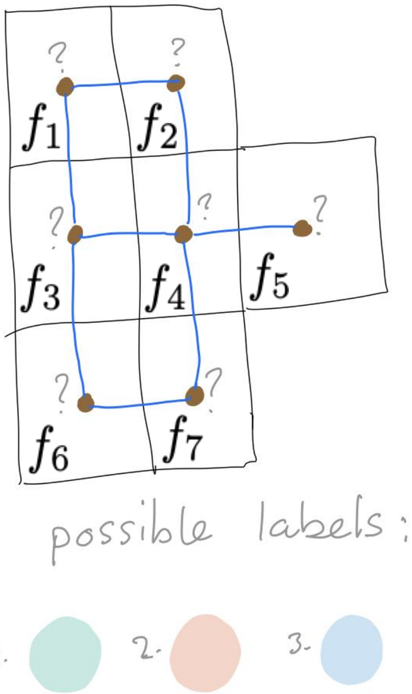


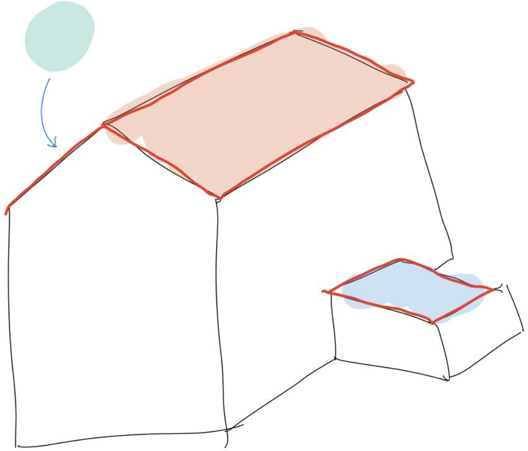
Graph-cut optimisation

Zebedin et al. (2008)

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

Dual graph of planar arrangement





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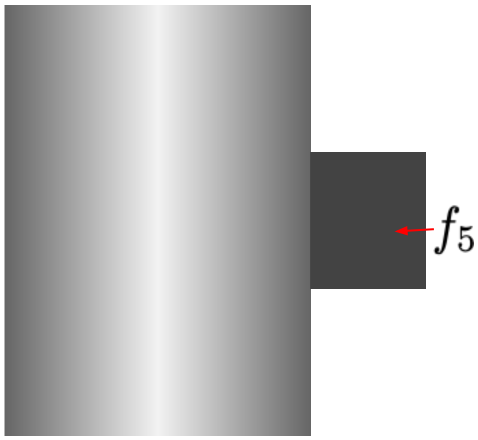
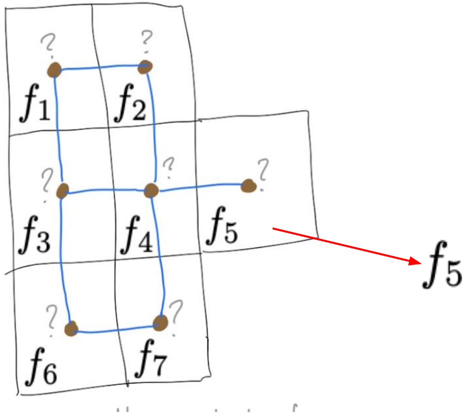
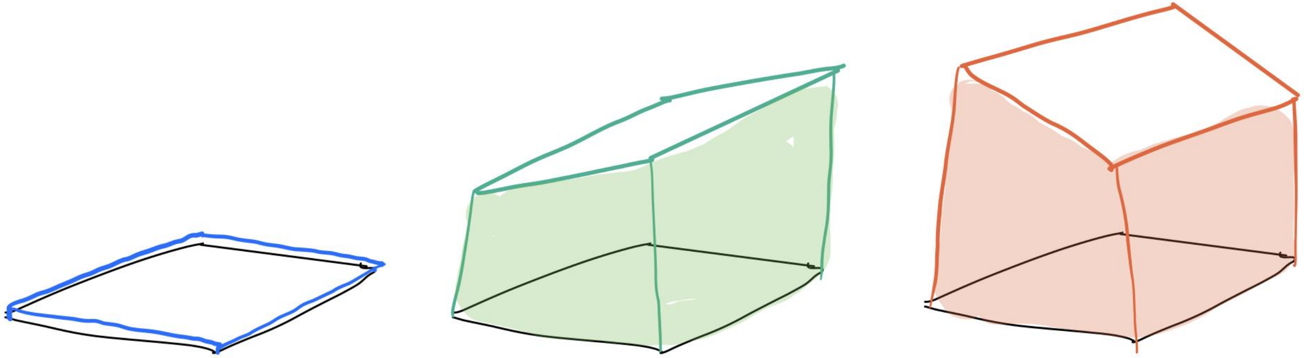


heightfield

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

Maximises data fit





Volume wrt each candidate plane

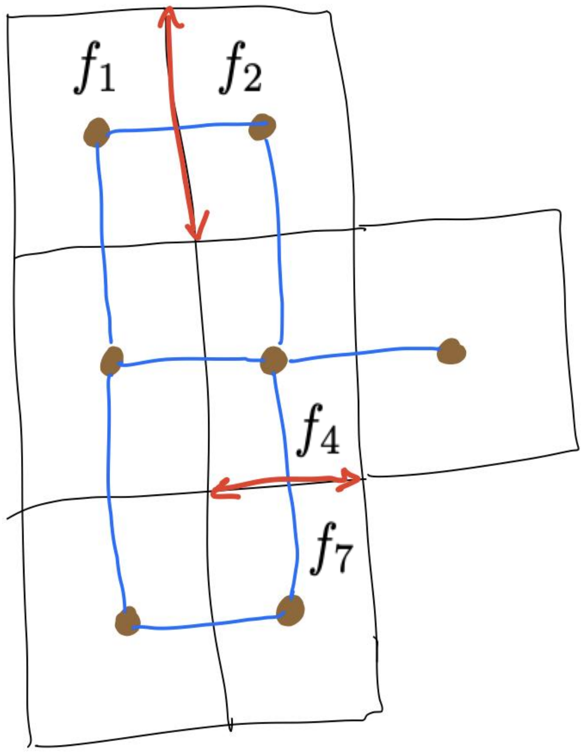
Graph-cut optimisation

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

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

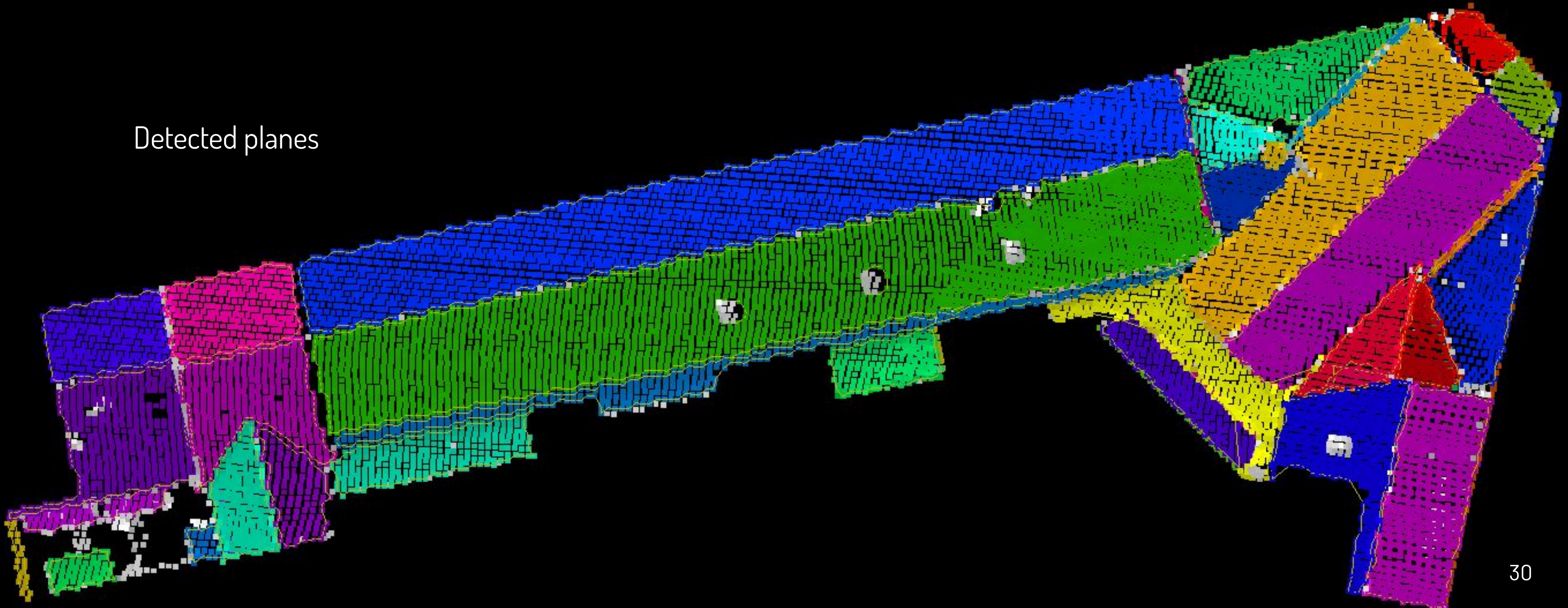
Smoothness term:
Edge length between adjacent faces with unequal plane label

Reduces complexity, discourages height discontinuities



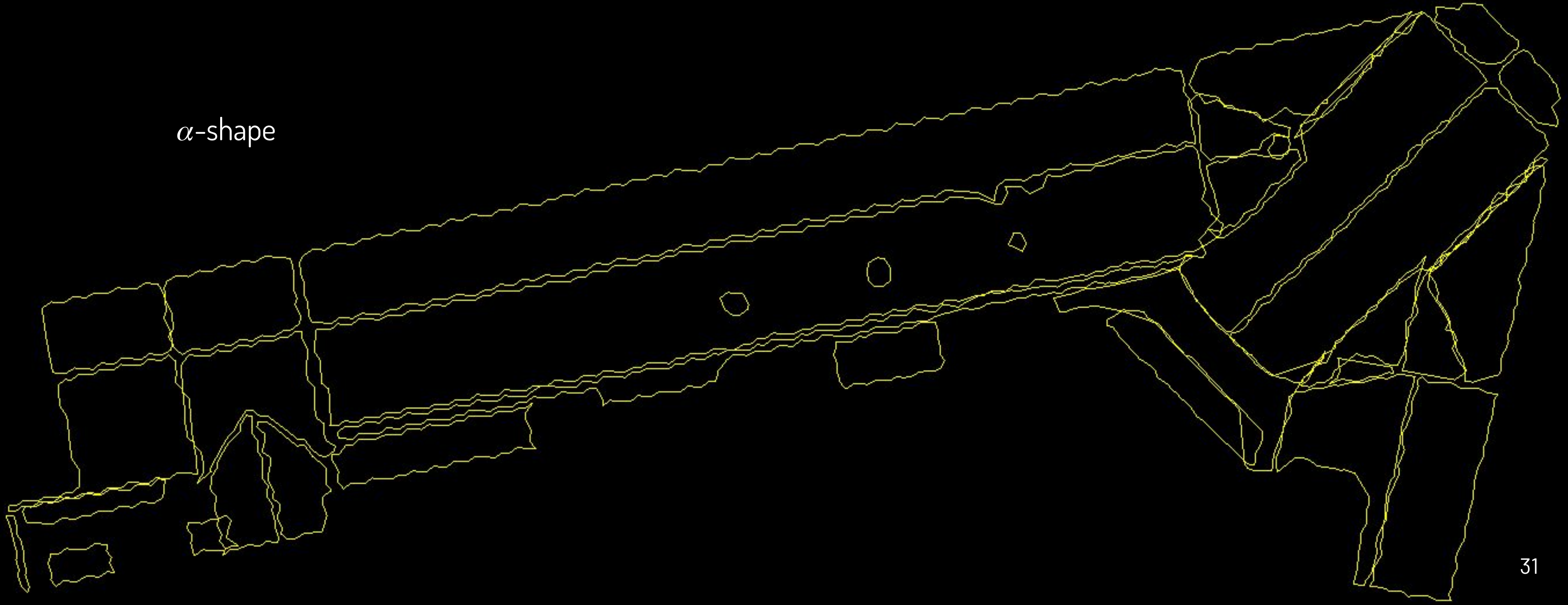
Heightfield

Detected planes



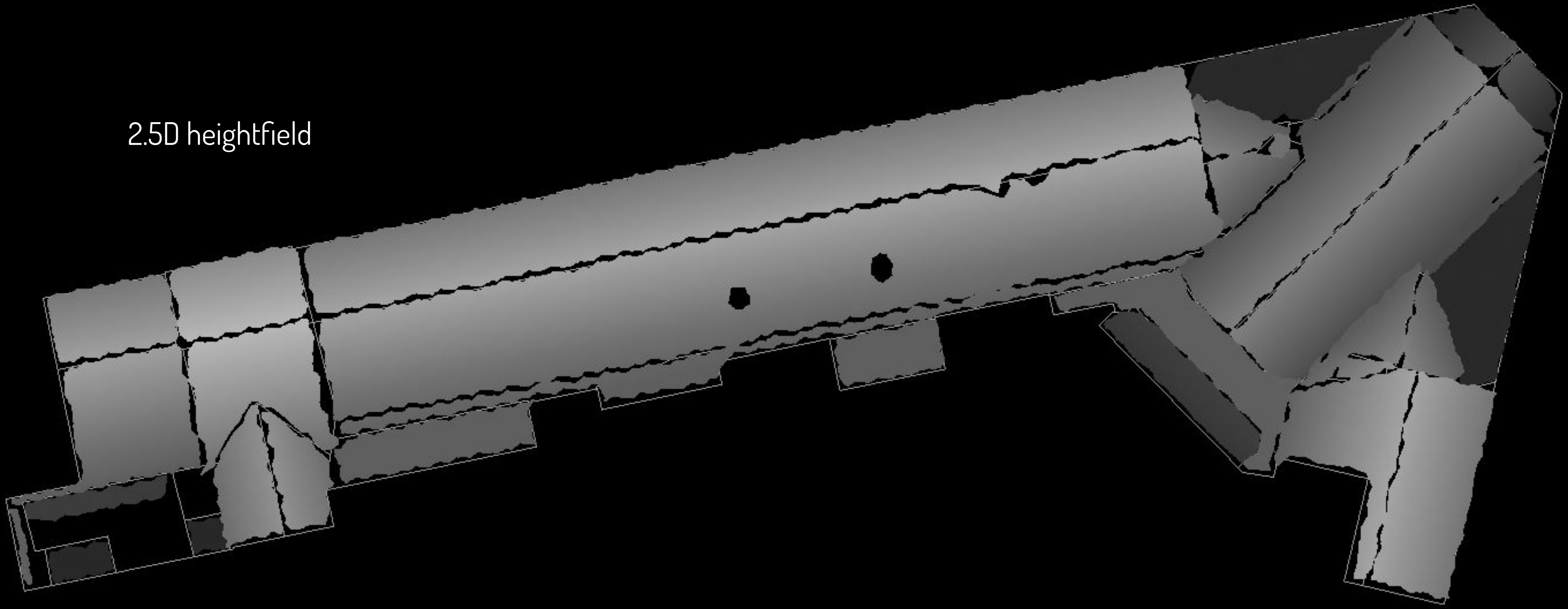
Heightfield

α-shape



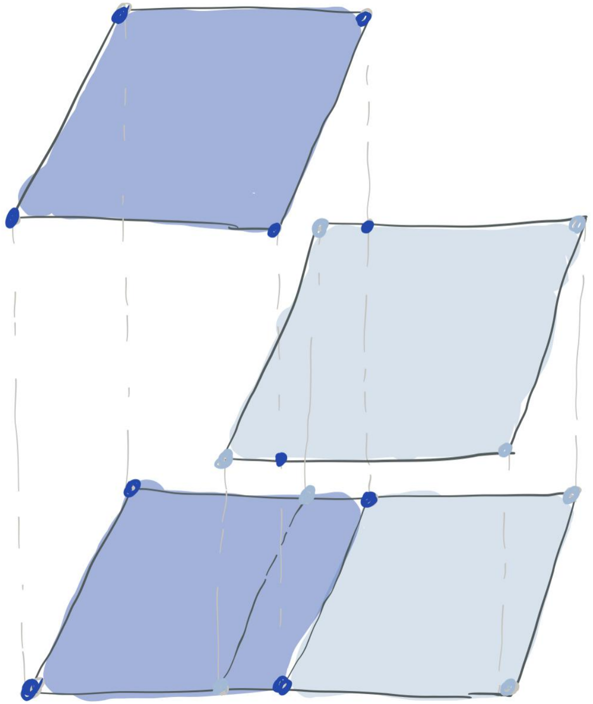
Heightfield

Only contains detected planes

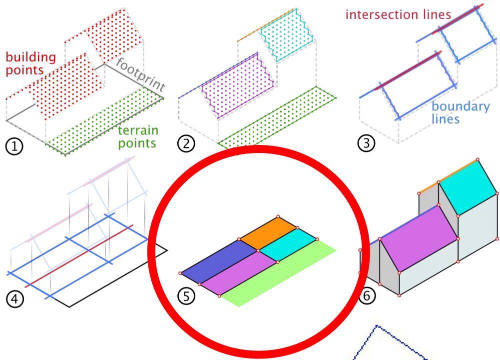


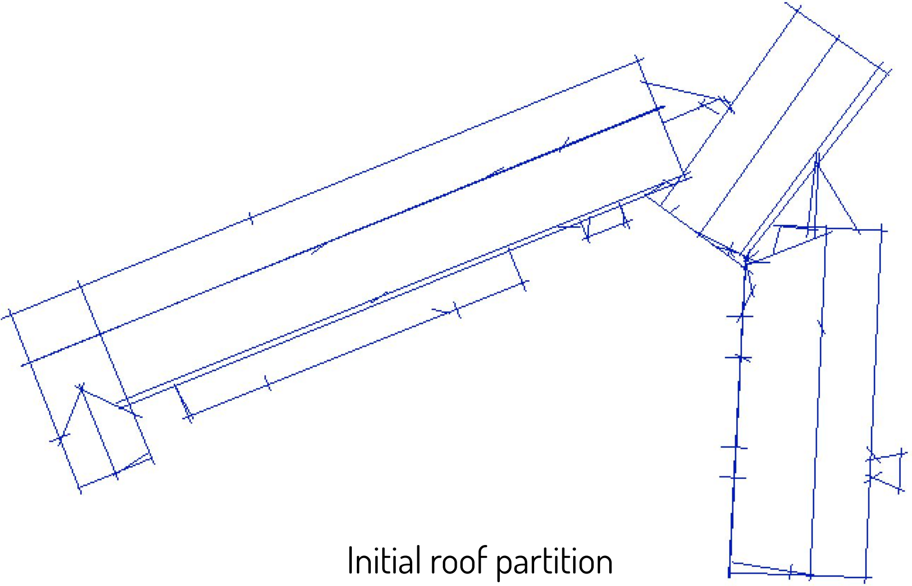
Heightfield

In case of overlap: keep highest elevation values

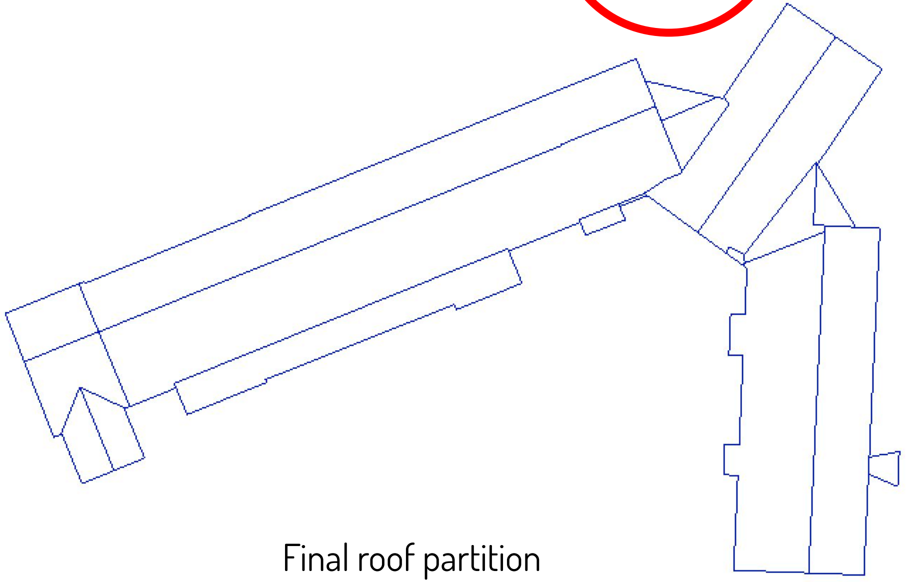


Final roof partition



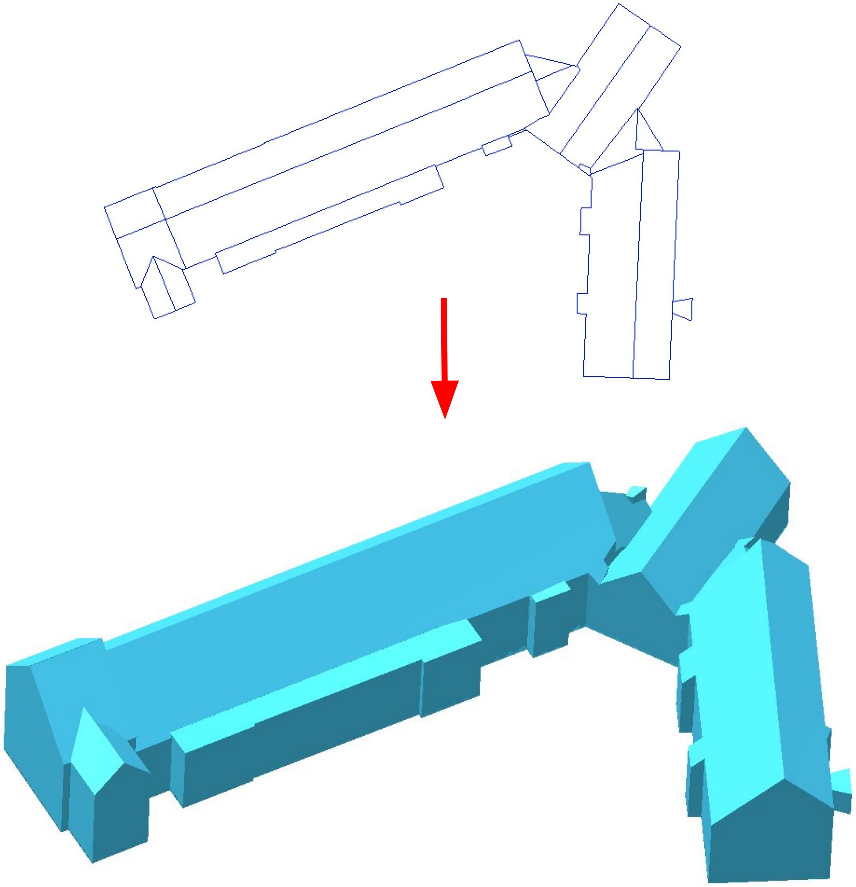


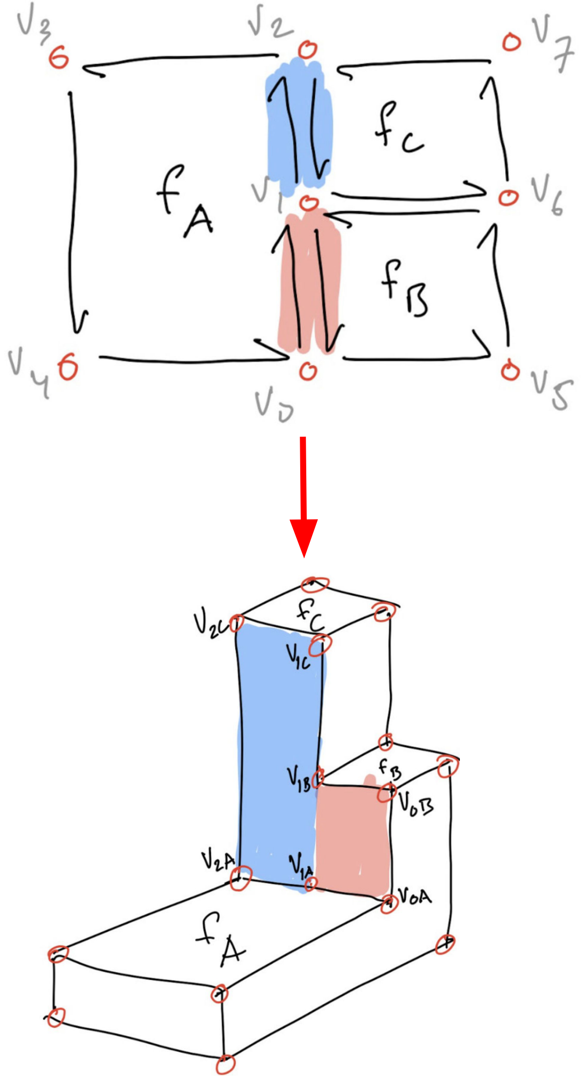
Initial roof partition



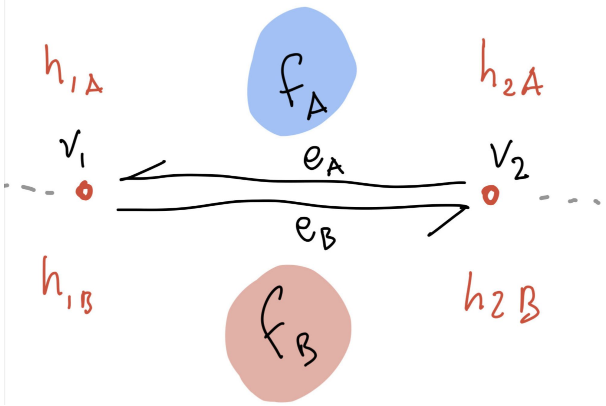
Final roof partition
(edges between equal plane labels dissolved)

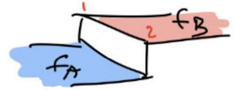
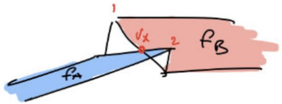
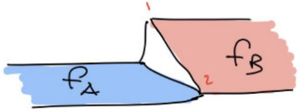
Extrusion





Extrusion



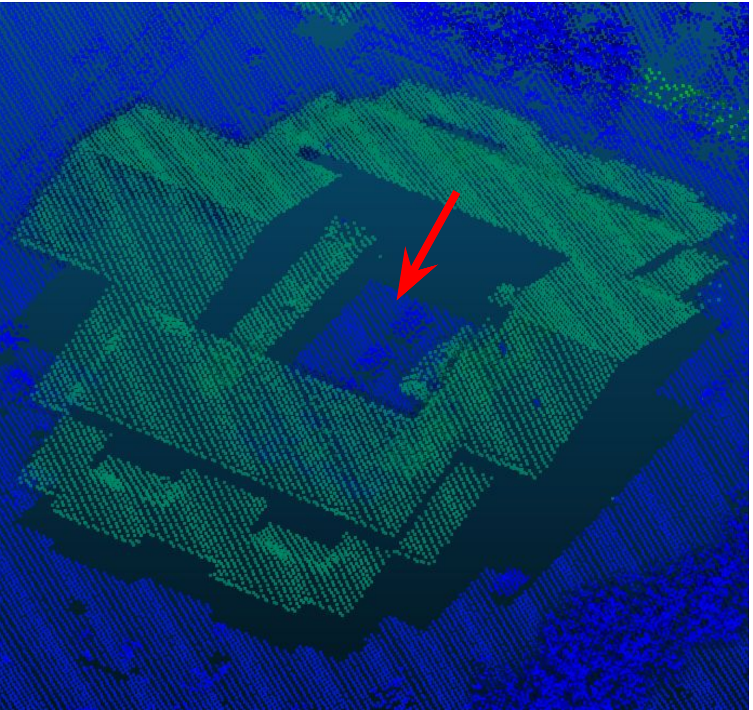
Case	condition	vertex order
	$h_{1A} < h_{1B}$ AND $h_{2A} < h_{2B}$	1. v_{1B}, v_{1A}, v_{2A}, v_{2B}
	$h_{1A} < h_{1B}$ AND $h_{2A} > h_{2B}$	1. v_{1B}, v_{1A}, v_x 2. v_{2A}, v_{2B}, v_x } 2 faces!
	$h_{1A} < h_{1B}$ AND $h_{2A} == h_{2B}$	1. v_{1B}, v_{1A}, v_{2A}

Special cases

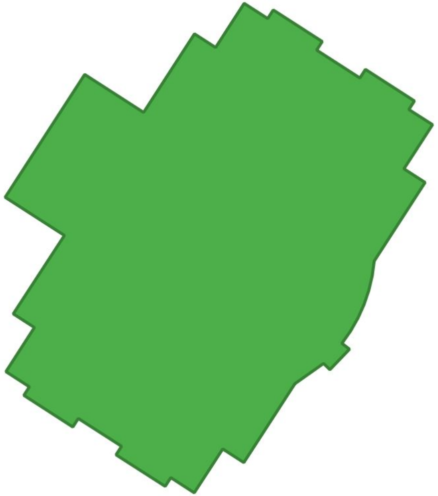
Groundparts

In some cases BAG footprint includes groundparts

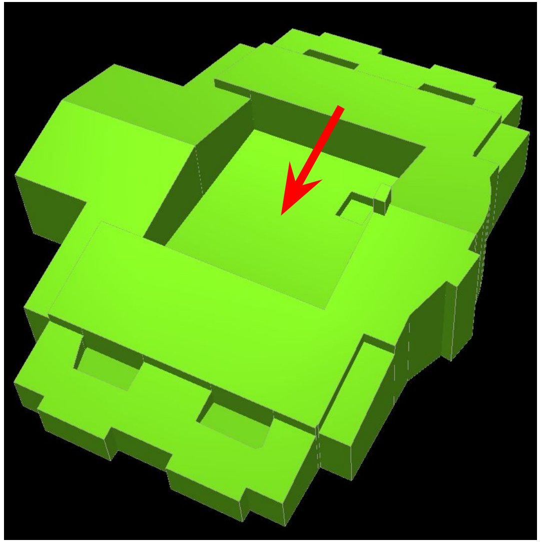
AHN3 ground and building class



BAG footprint



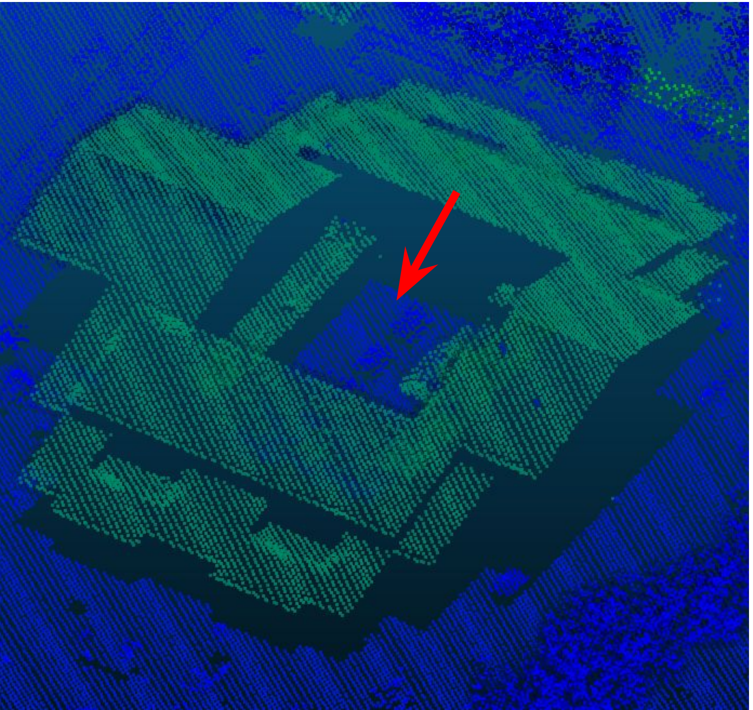
Reconstruction result:
roofplane fitted to groundpart



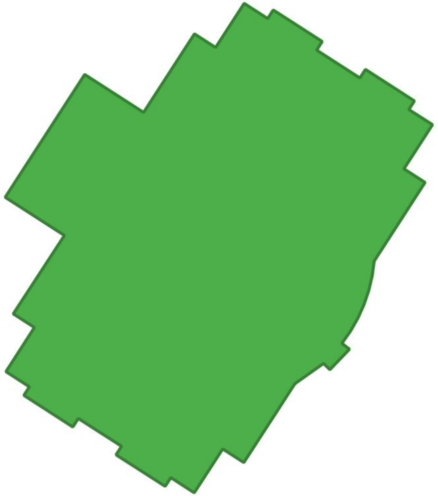
Groundparts

Reconstruction with groundpart detection

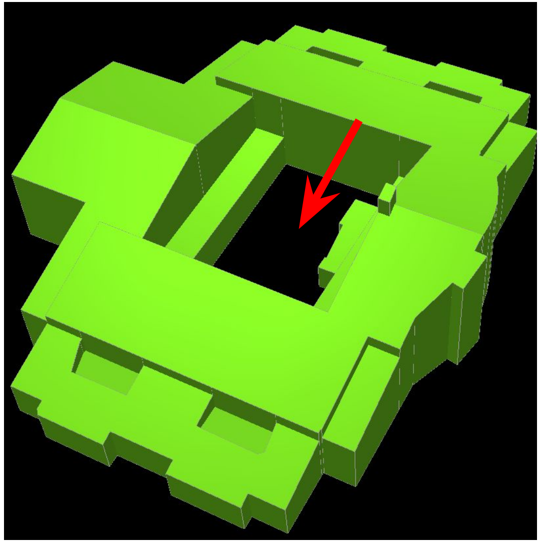
AHN3 ground and building class



BAG footprint

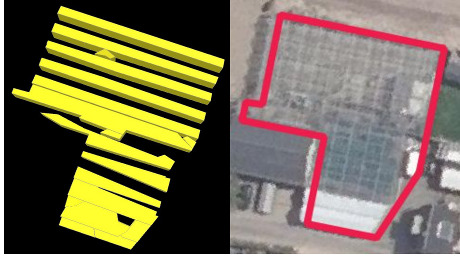


Reconstruction result:
groundpart removed from output



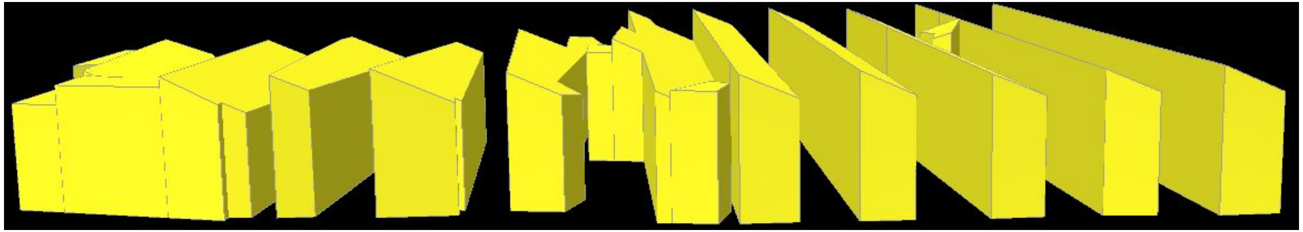
Limitation: glass roofs

Green houses: both points on ground and on roof



AHN3
ground and building class

Heightfield



Reconstruction result

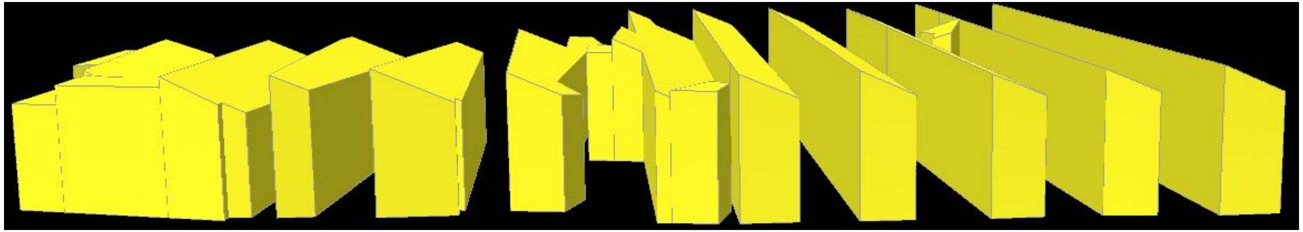
Limitation: glass roofs

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

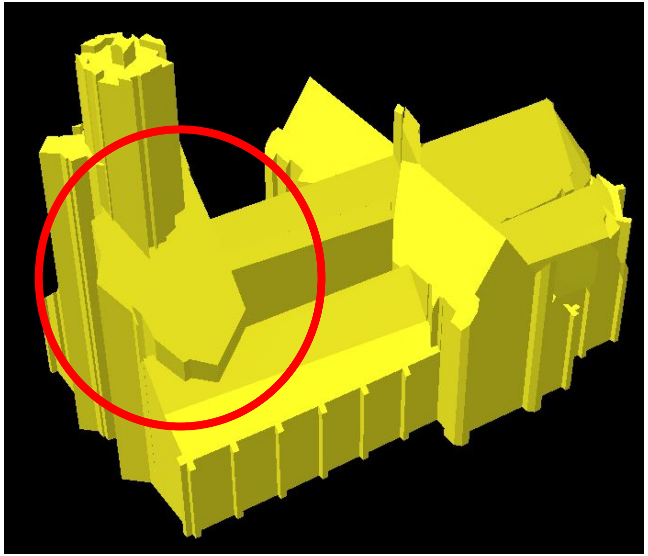


Reconstruction result

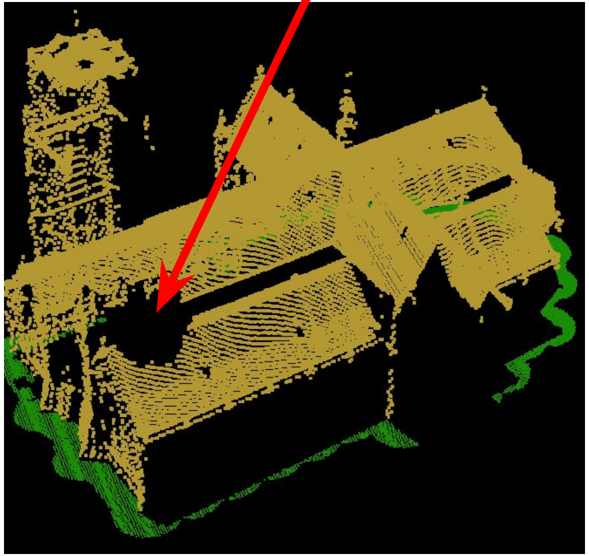
Limitations: occlusion/no-data

Possible solution:
Smartly fill no-data areas?

Occlusion/no-data



Reconstruction



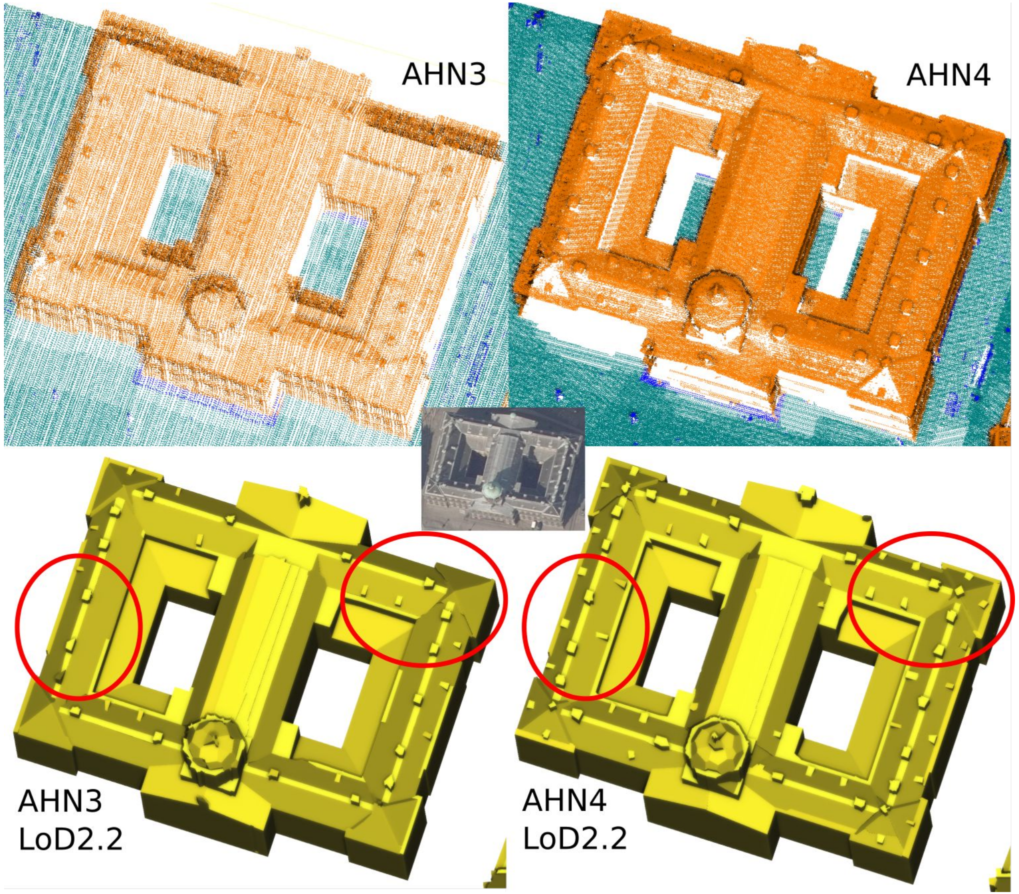
AHN3 ground and building class

Heightfield

Spherical surfaces

Are approximated with planar surfaces if sufficient point density

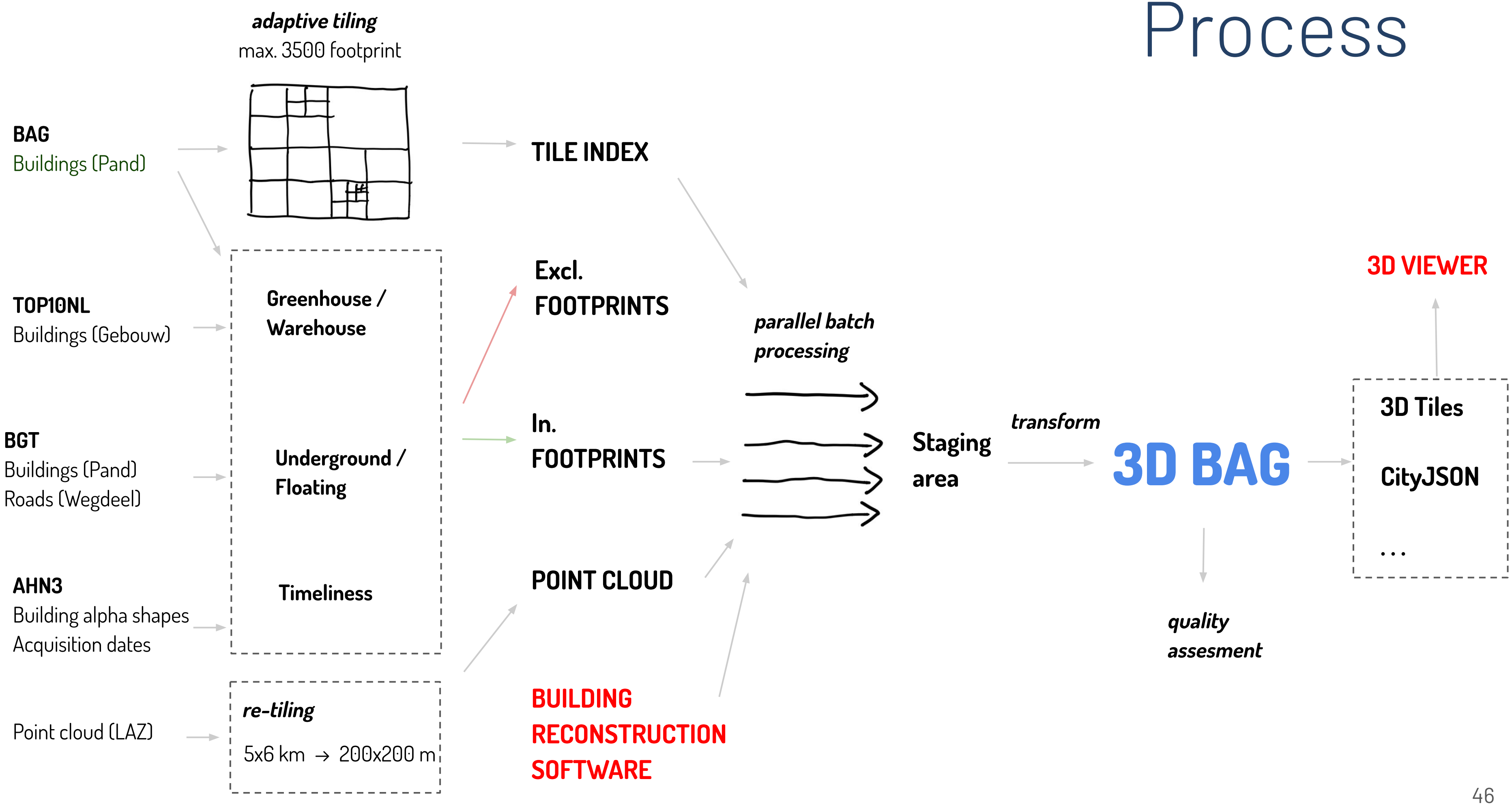
Effect of point density input point cloud



~2x point density

Data management

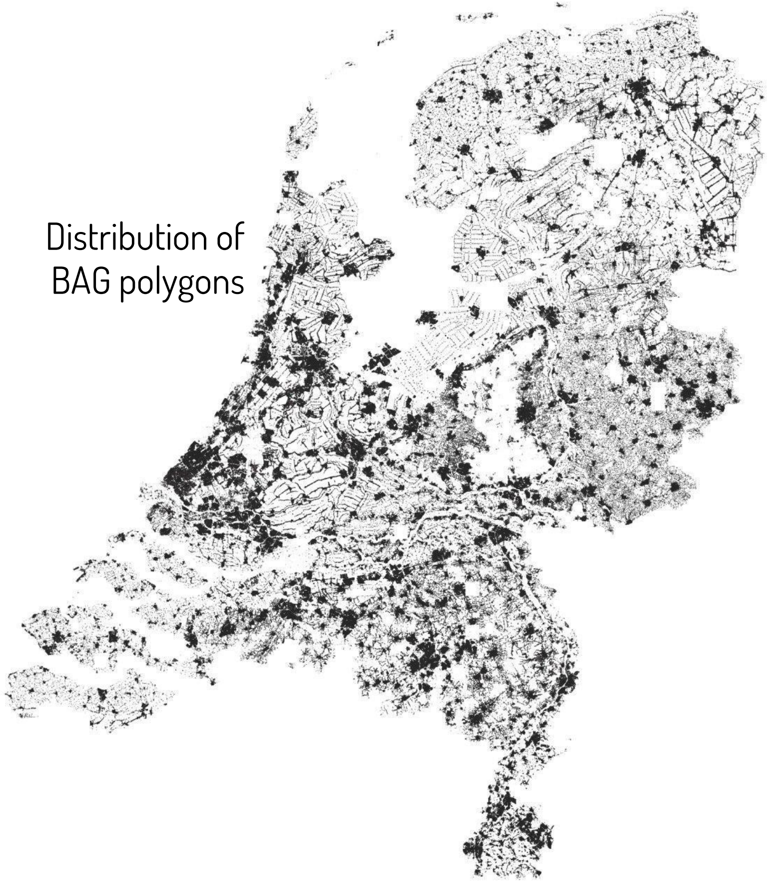
Process

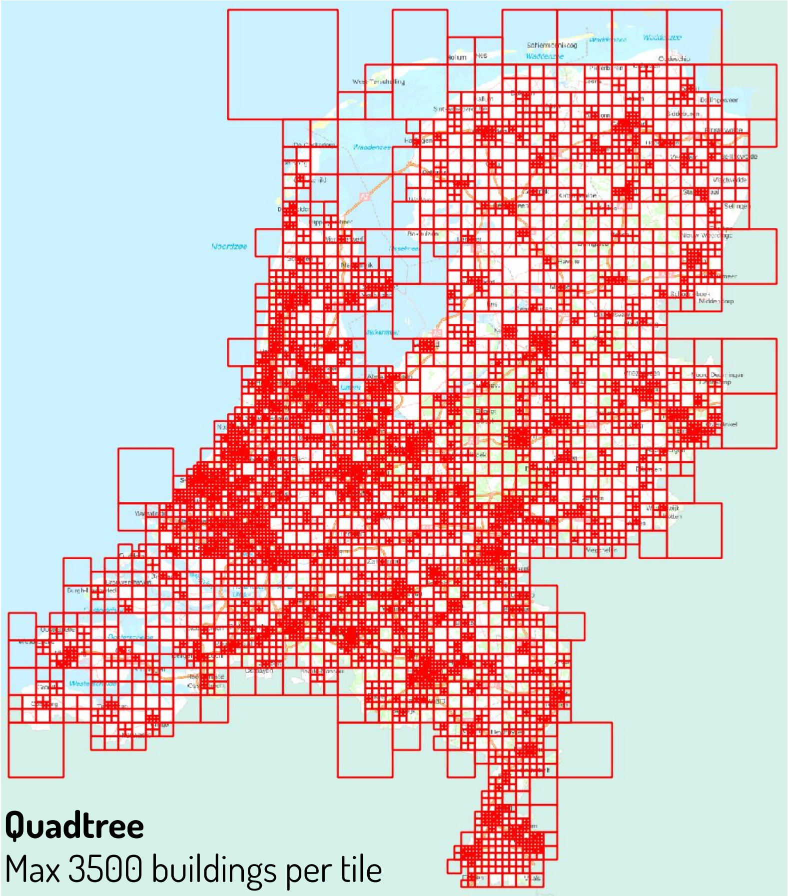


adaptive tiling
max. 3500 footprint
BAG
Buildings (Pand)
TOP10NL
Buildings (Gebouw)
BGT
Buildings (Pand)
Roads (Wegdeel)
AHN3
Building alpha shapes
Acquisition dates
Point cloud (LAZ)
Greenhouse / Warehouse
Underground / Floating
Timeliness
re-tiling
5x6 km → 200x200 m
TILE INDEX
Excl. FOOTPRINTS
In. FOOTPRINTS
POINT CLOUD
BUILDING RECONSTRUCTION SOFTWARE
parallel batch processing
Staging area
transform
3D BAG
quality assesment
3D VIEWER
3D Tiles
CityJSON
...

How to smartly tile the data?

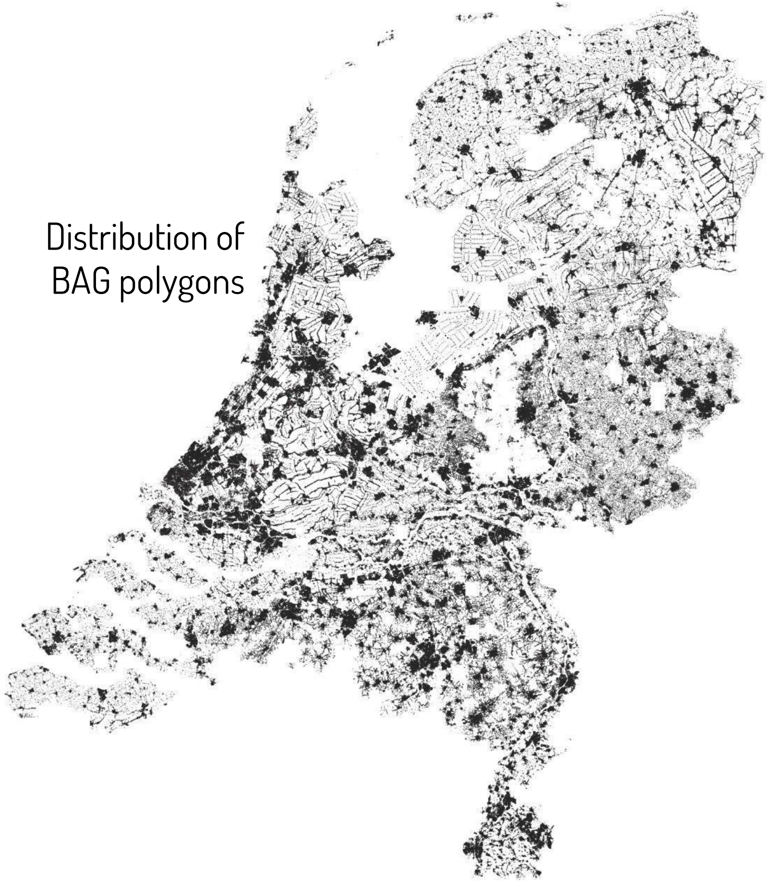
Distribution of BAG polygons



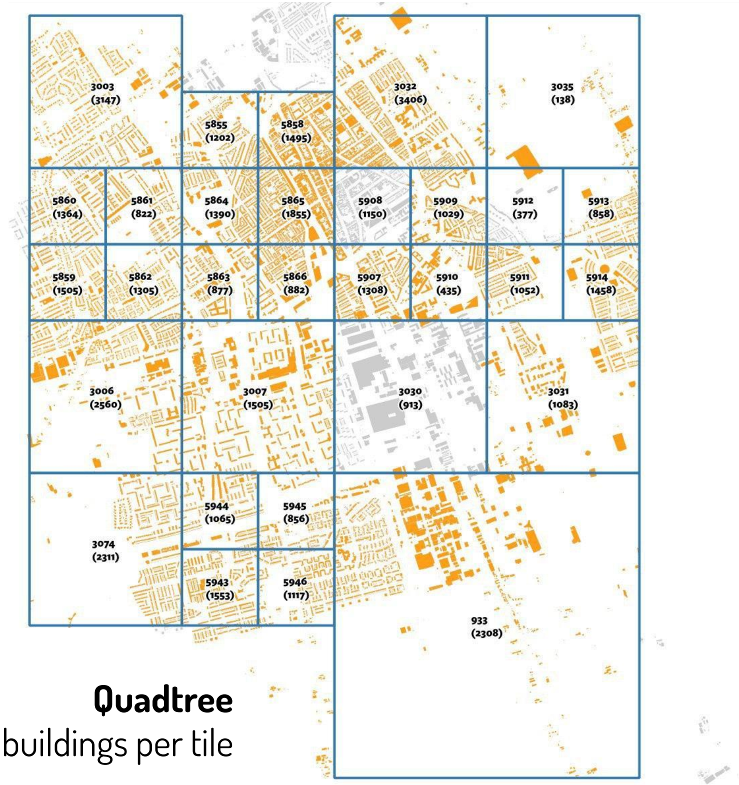


Quadtree
Max 3500 buildings per tile

How to smartly tile the data?



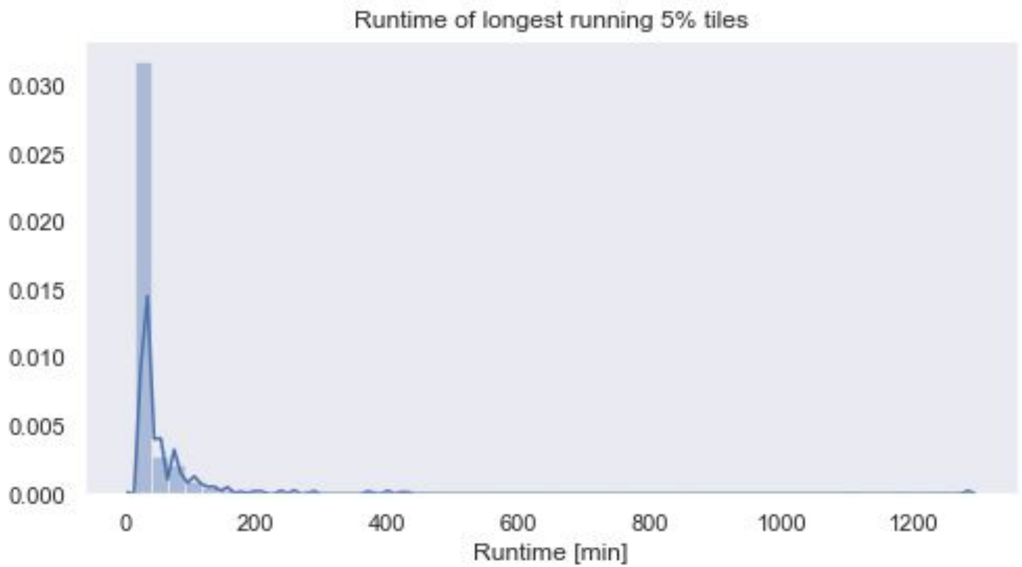
Distribution of BAG polygons



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)

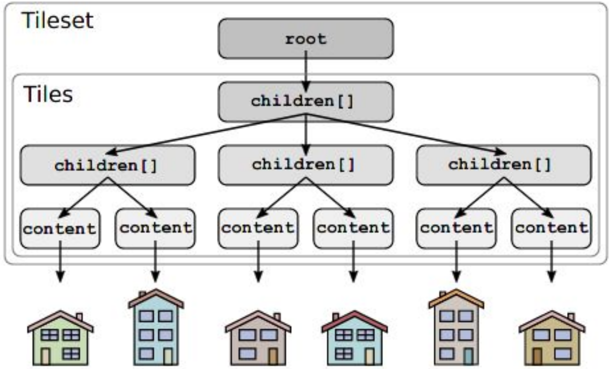


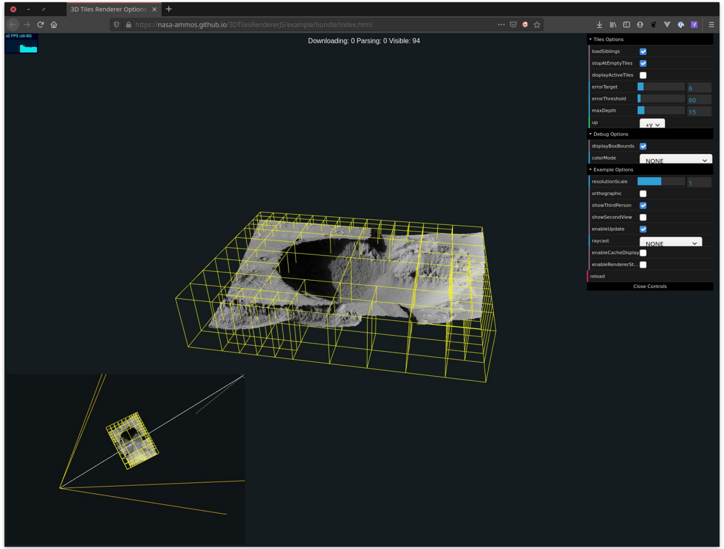
Reconstruction time ***per building,***
for all LoD-s,
excl. I/O,
milliseconds

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

Good tiling also important for 3D viewer

- We use quadtree and 3D tiles standard
- Only download tiles in camera frustum
- Big tiles load slowly





https://nasa-ammos.github.io/3DTilesRendererJS/example/bundle/index.html

3D BAG v2 current status

Planned public release next month (March 2021)

In the meantime you can access our beta at:

https://tudelft3d.github.io/3dbag-viewer/

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

3D geoinformation
Department of Urbanism
Faculty of Architecture and the Built Environment
Delft University of Technology