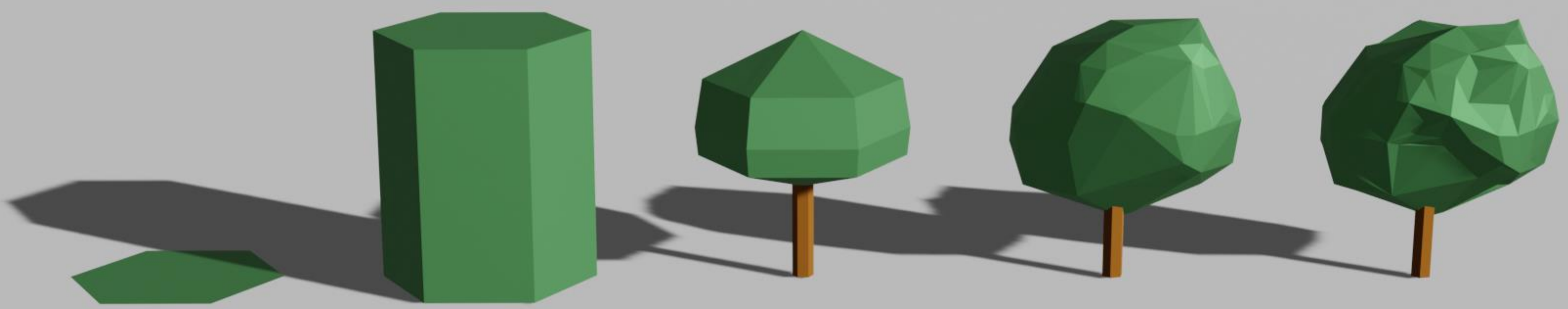
Automatic construction of 3D tree models from airborne LiDAR data in multiple levels of detail



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TU Delft

Supervisors:
Prof. dr. Jantien Stoter
Dr. Hugo Ledoux

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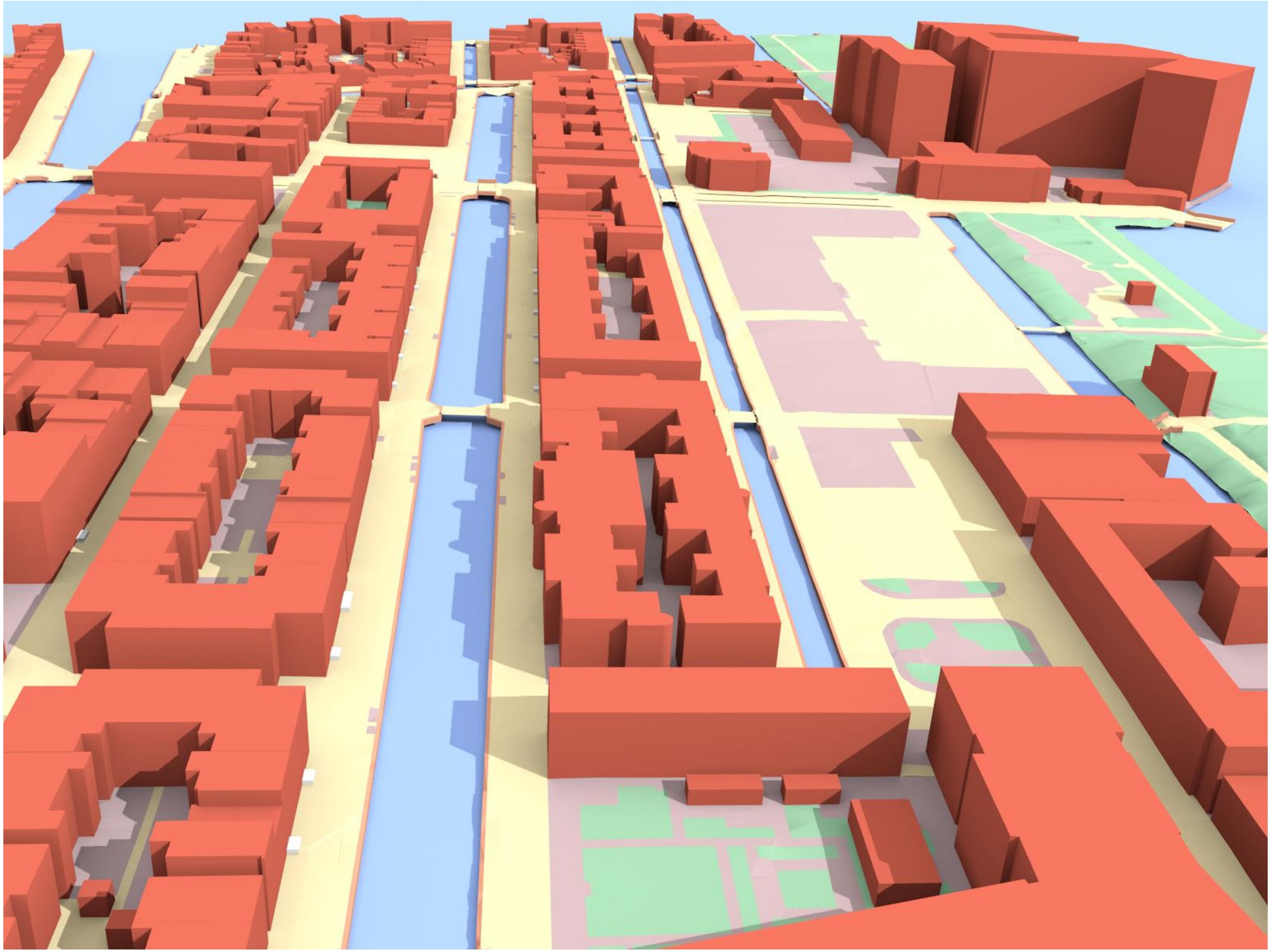

3dfier output (3D Geoinformation Group, 2019)

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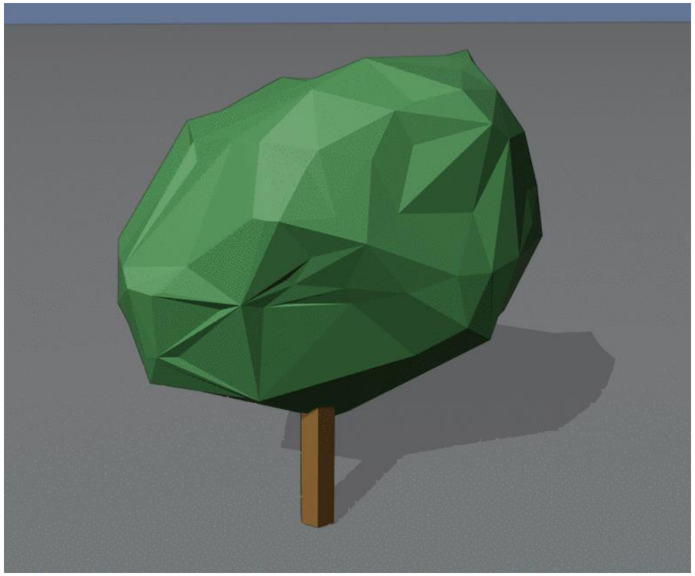

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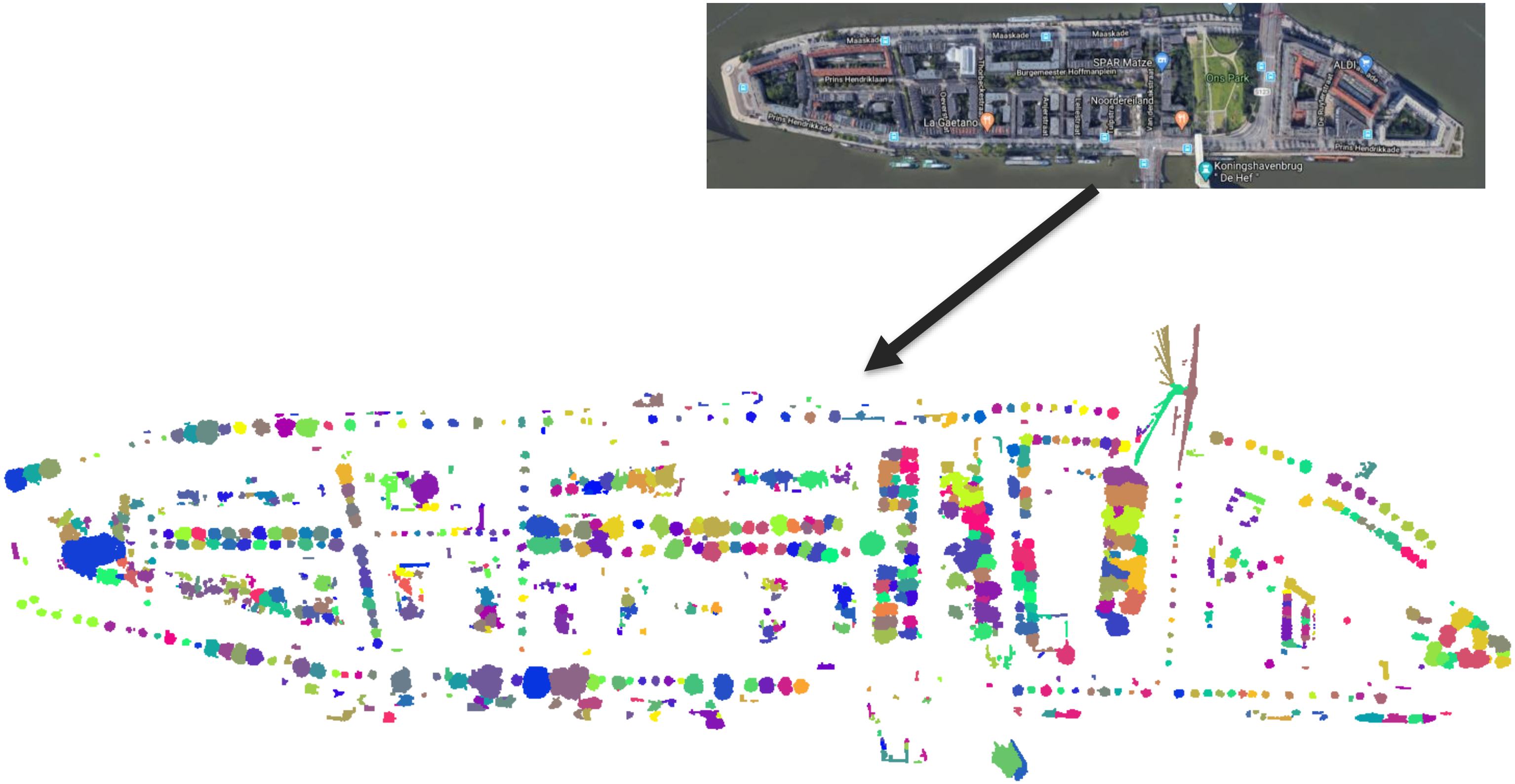
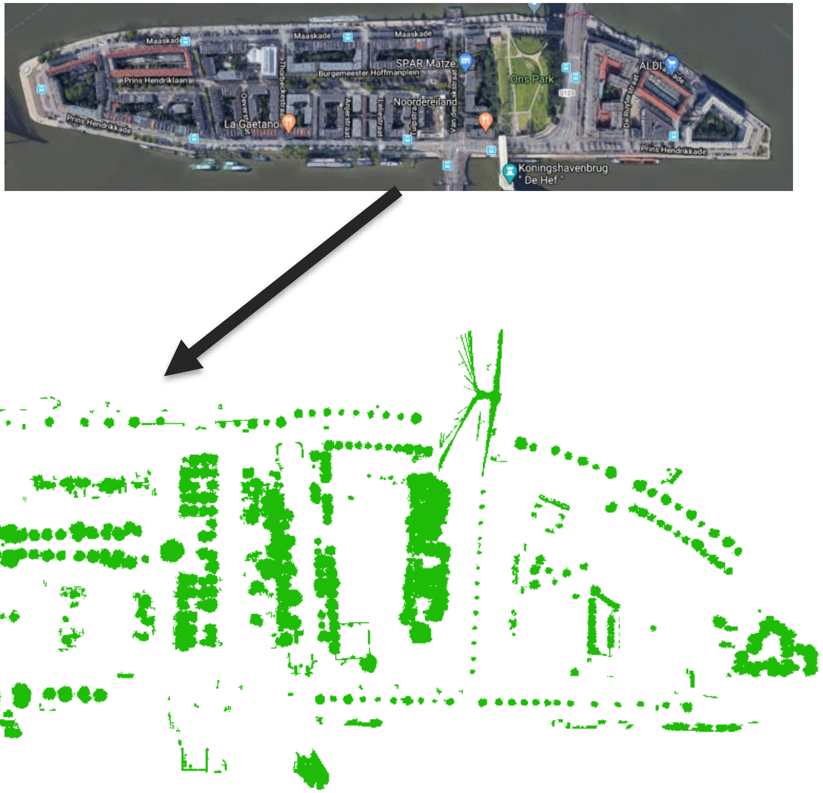


Maaskade
Maaskade
Maaskade
SPAR Matze
Burgemeester Hoffmanplein
Prins Hendriklaan
Ons Park
ALDI
Noordereiland
La Gaetano
Prins Hendrikkade
Prins Hendrikkade
Koningshavenbrug
"De Hef"

Goal



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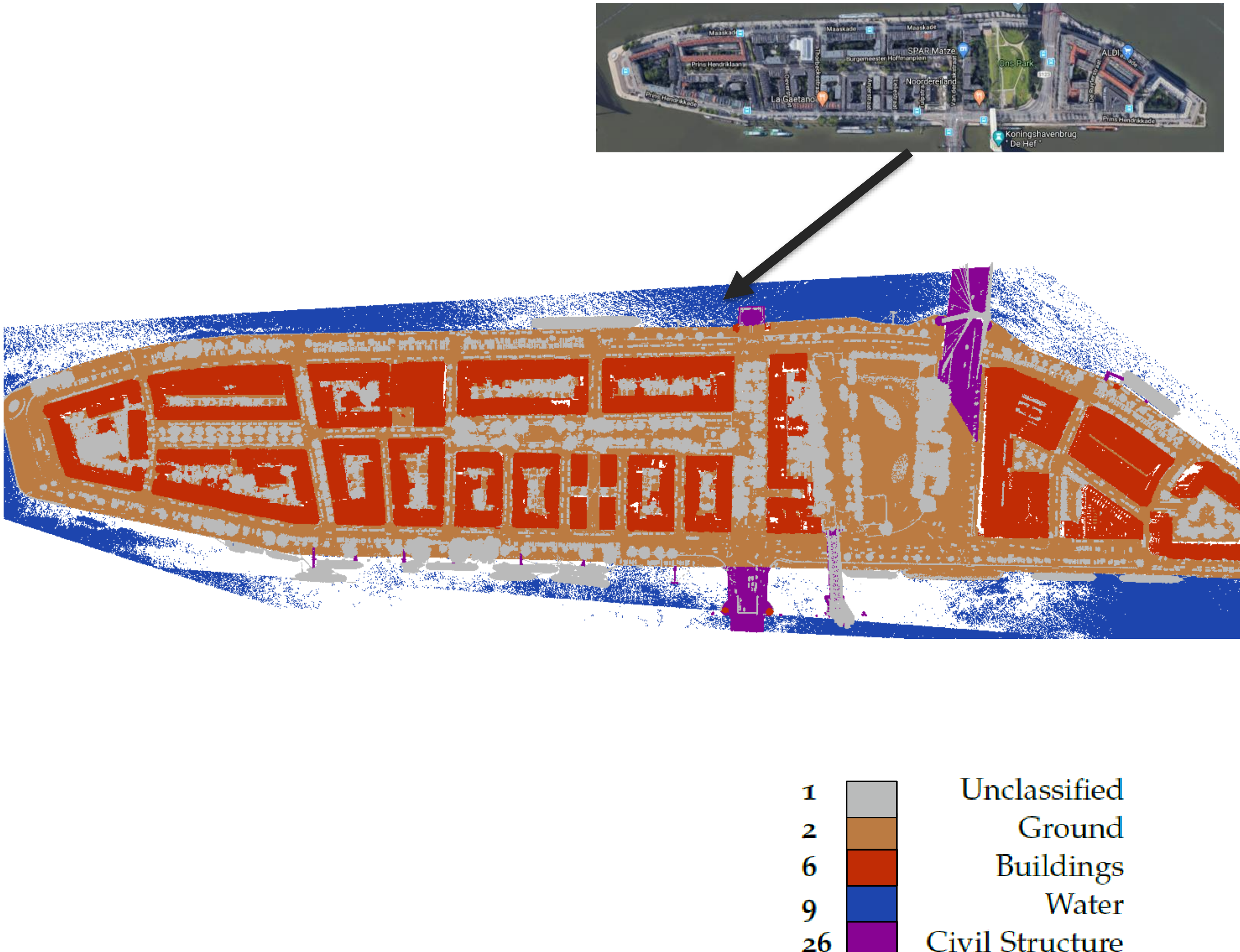

Research Questions

How can 3D tree models at varying Levels of Detail be automatically constructed from airborne LiDAR point cloud data?

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Research Questions

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How can 3D tree models at varying Levels of Detail be automatically constructed from airborne LiDAR point cloud data?

1. *What applications require what type or Level of Detail (LOD) of 3D tree models?*
2. *What LODs are most fitting for which type of tree models (single vegetation object or vegetation group)?*
3. *How can a final implementation be made to fit into the 3dfier pipeline?*
4. *Is it possible to determine which tree type a tree belongs to, based on features that can be extracted from trees in airborne LiDAR point cloud data?*

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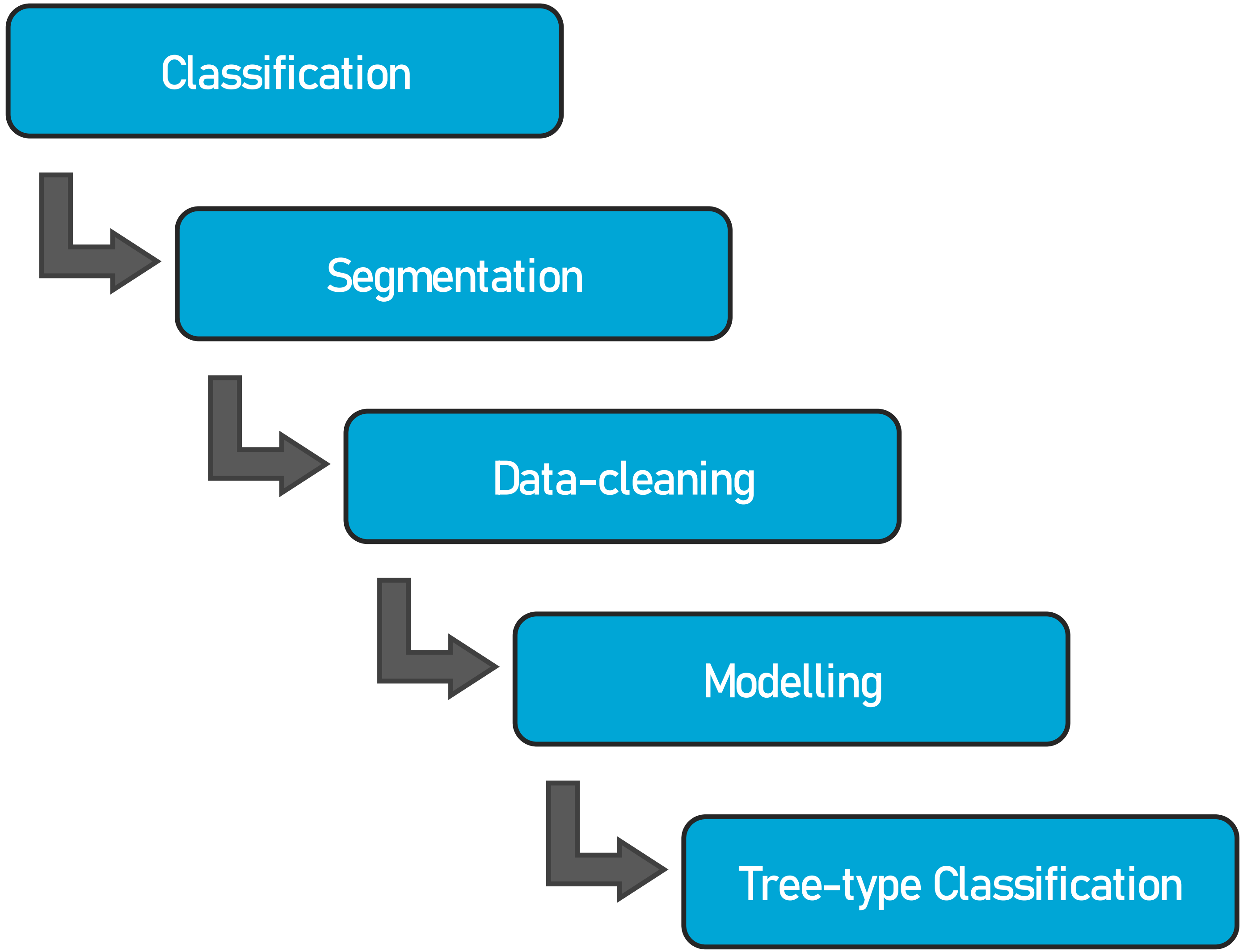
Approach



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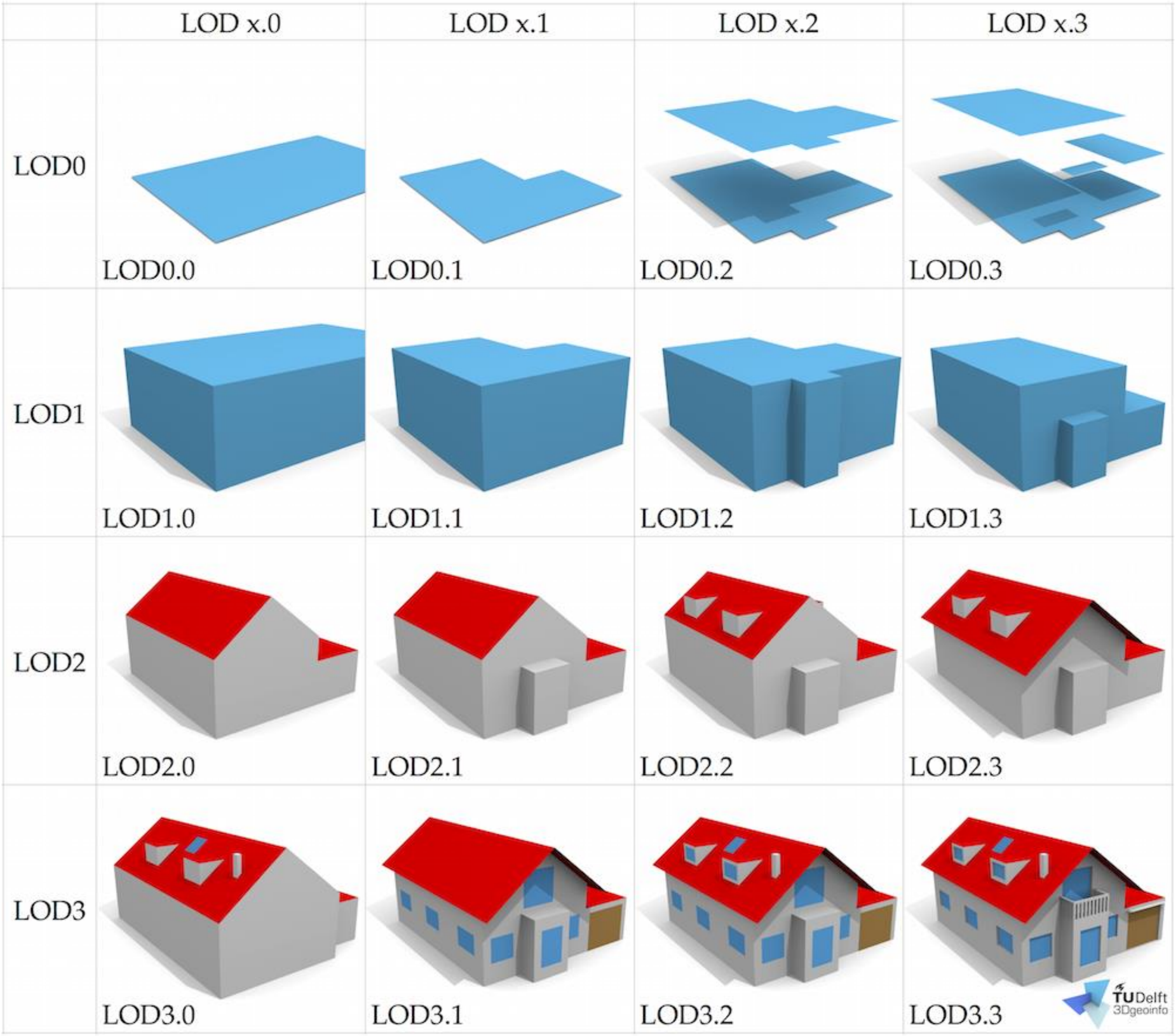

LOD Specifications (Biljecki et al., 2016)

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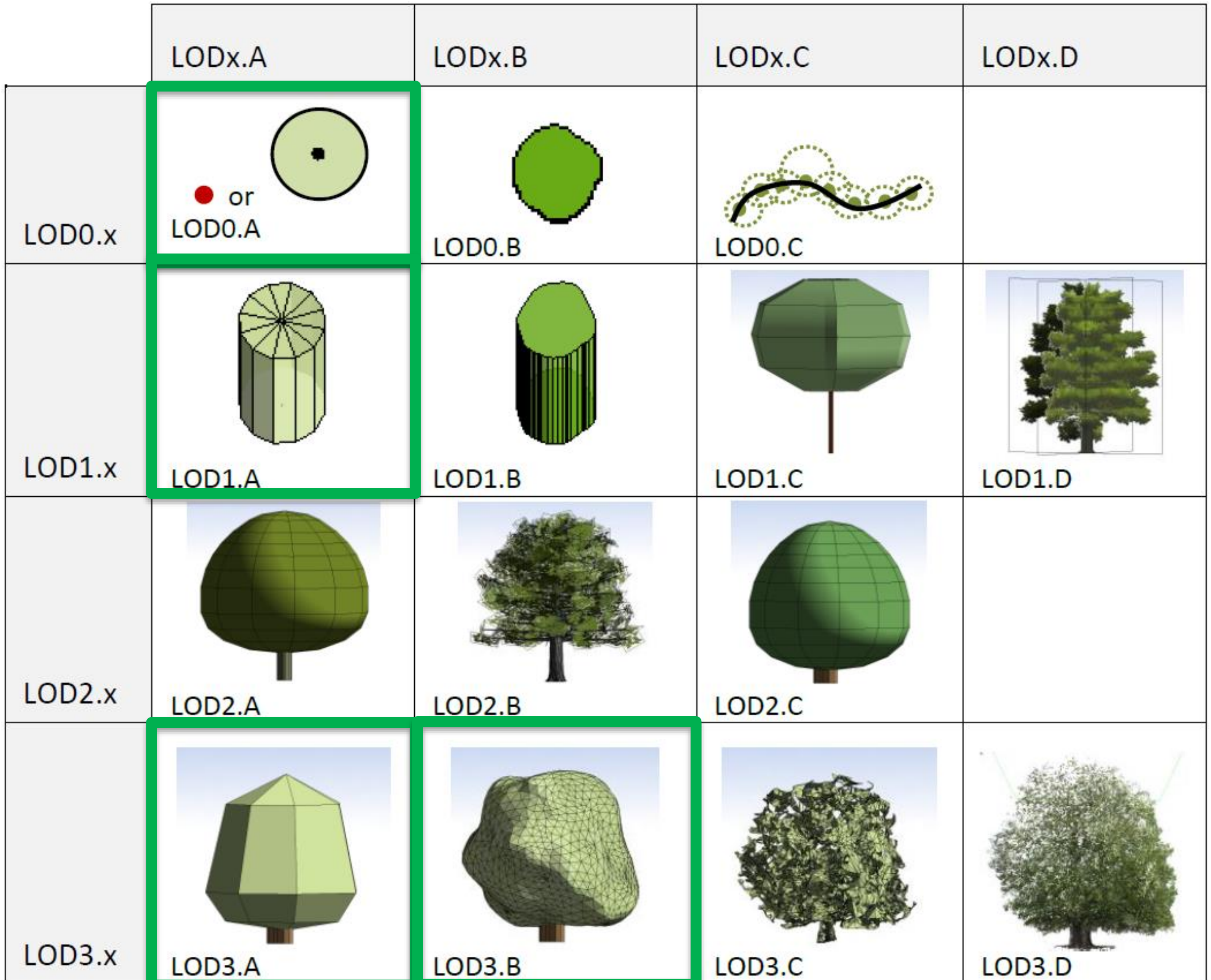


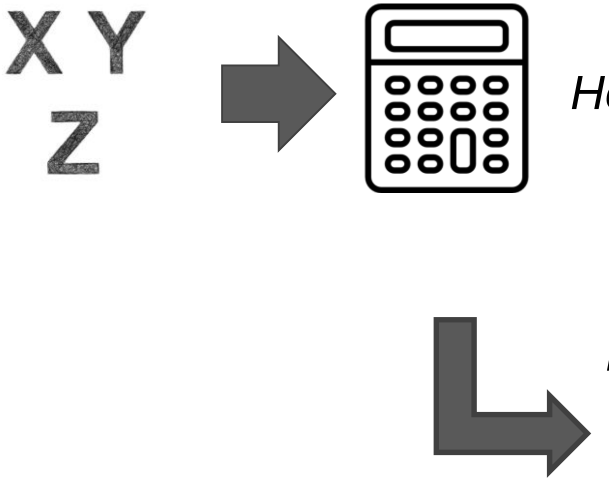
LOD Proposal (Ortega-C'ordova, 2018)

Proposal

LOD0 *LOD1* *LOD2* *LOD3.0* *LOD3.1*

Classification

Actueel Hoogtebestand Nederland



Height from ground

Planarity

Ruggedness

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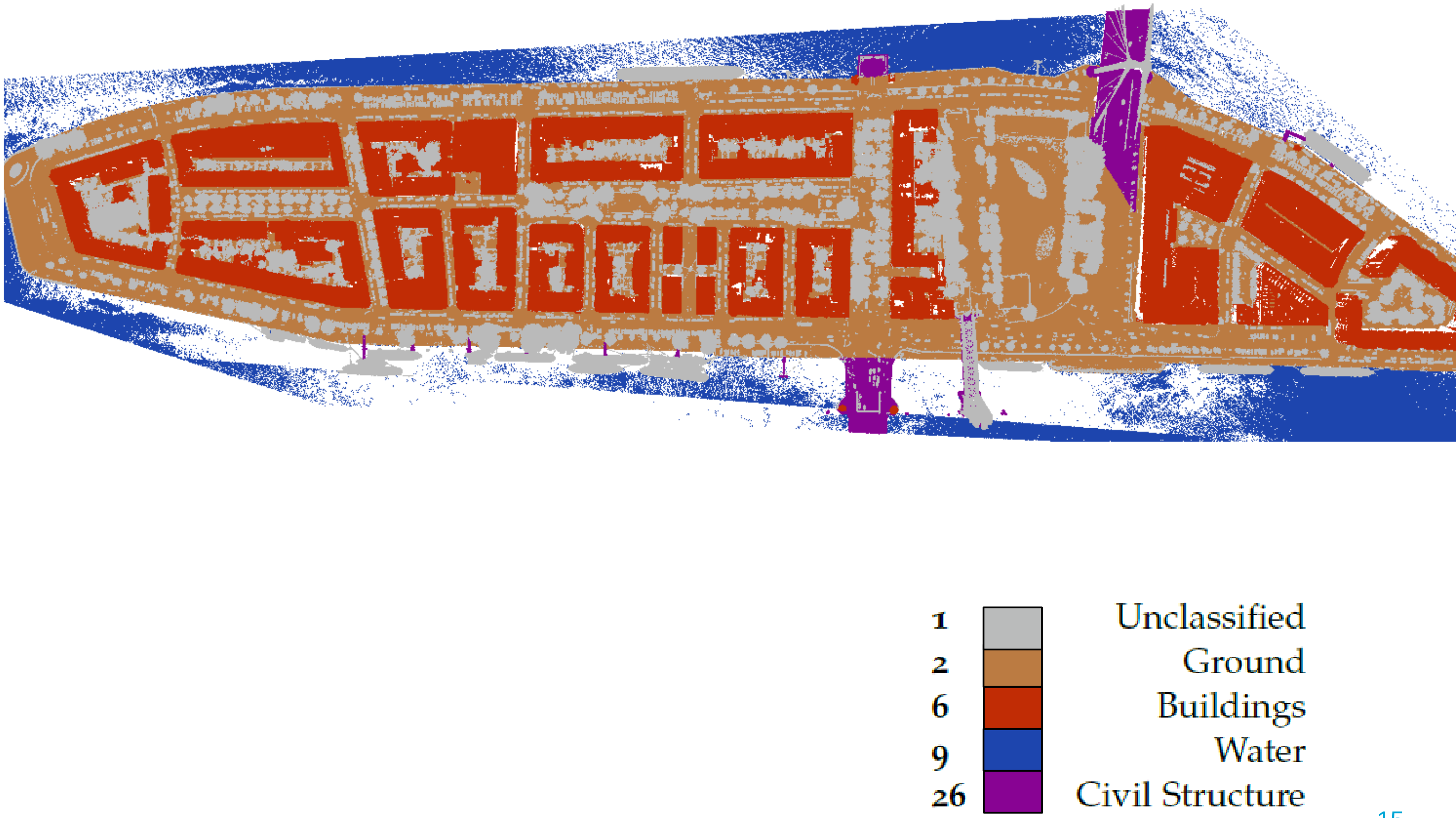

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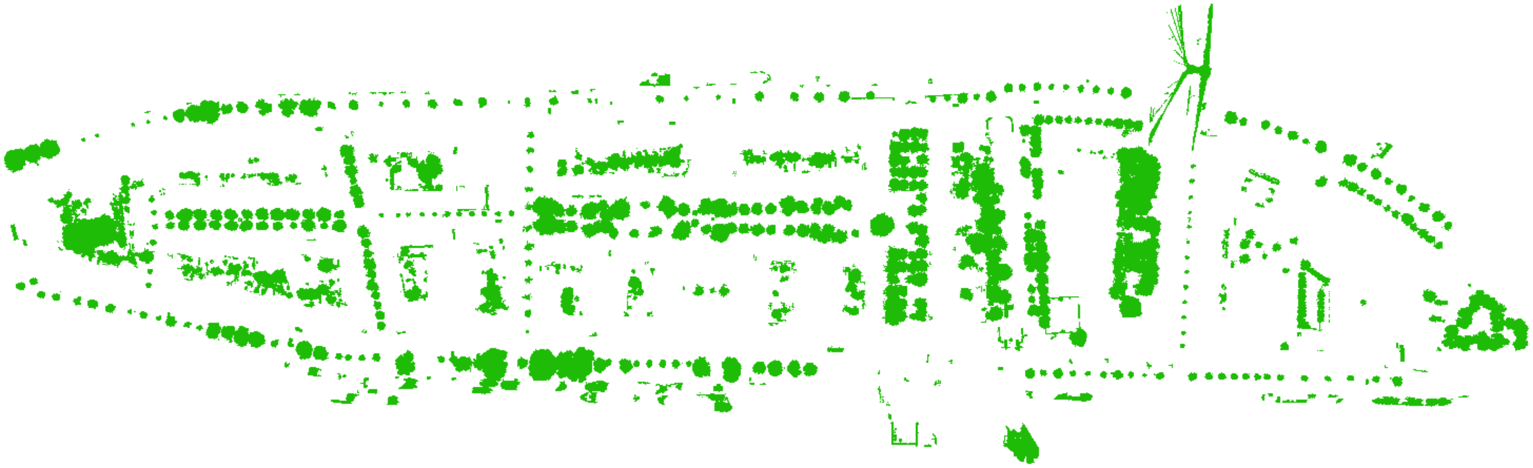

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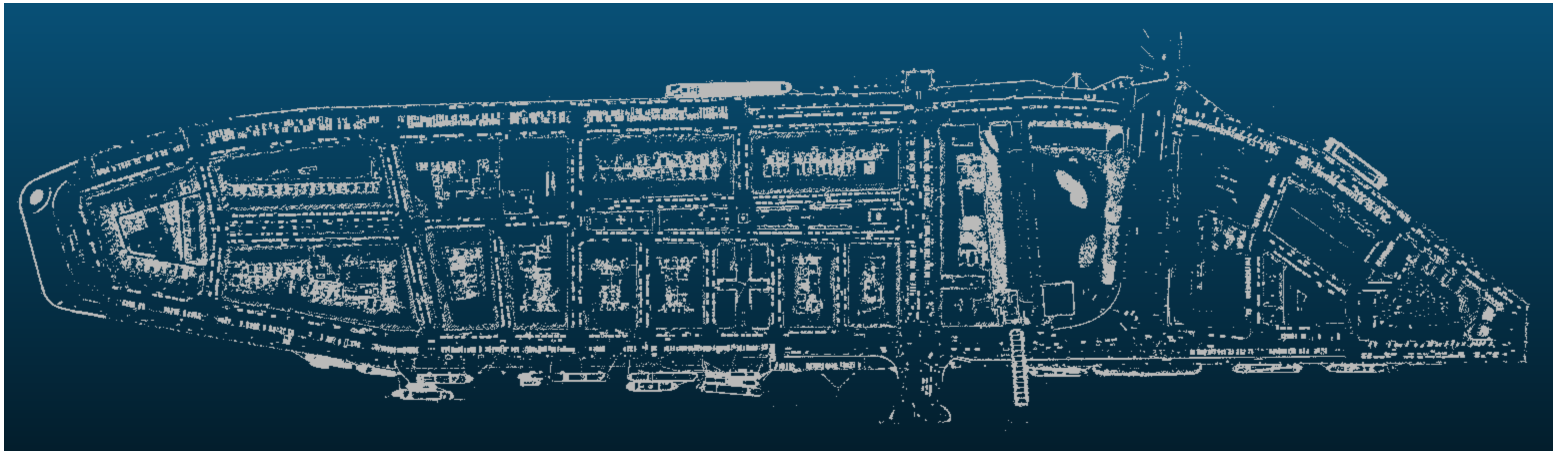

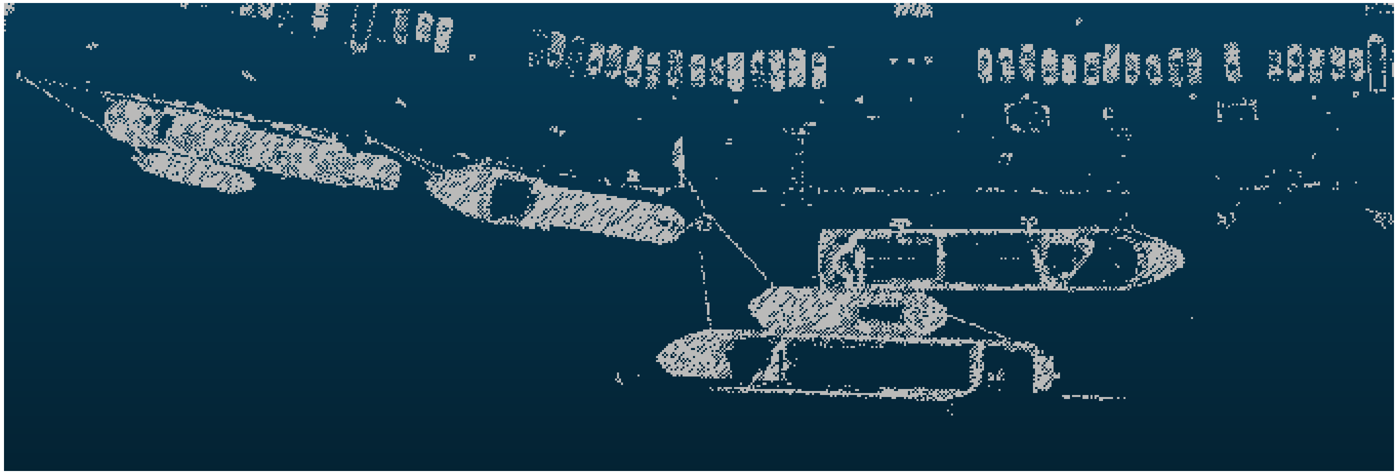

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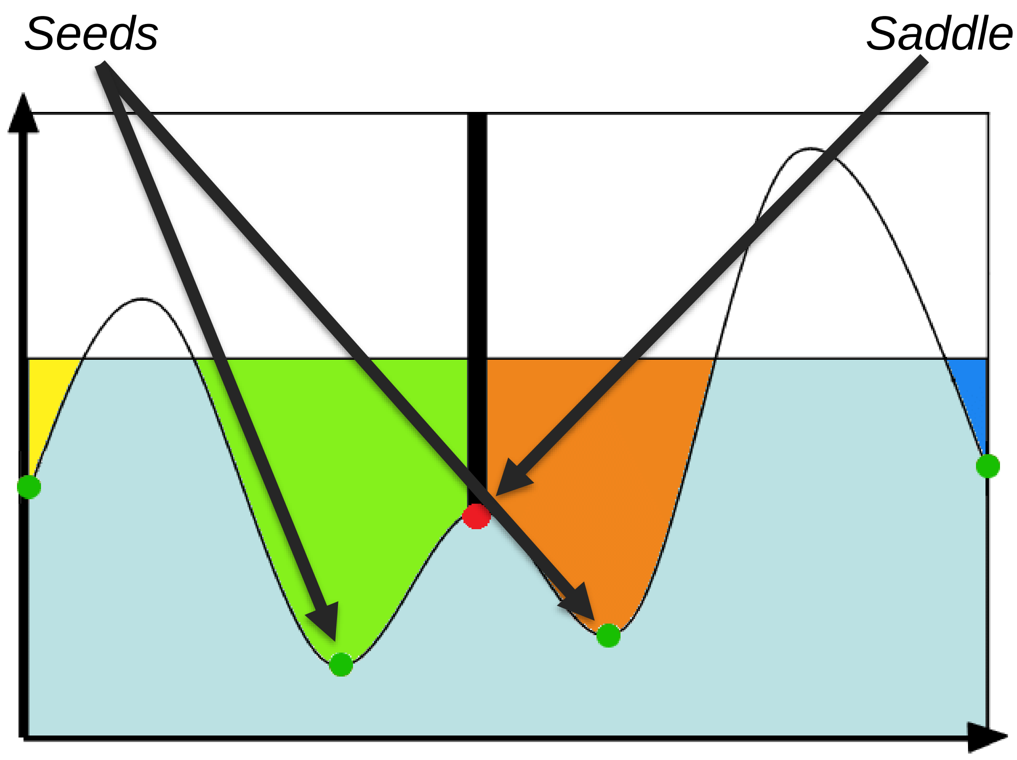
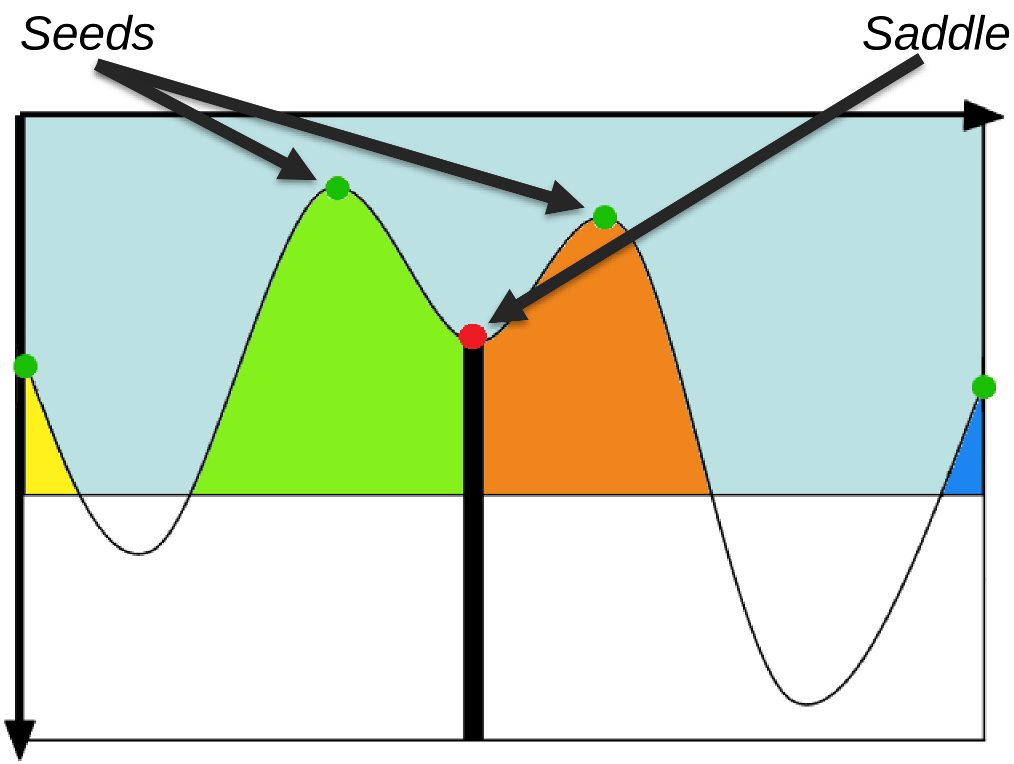


Watershed segmentation (Roudier et Al., 2008)

Segmentation



Watershed segmentation (Roudier et Al., 2008)

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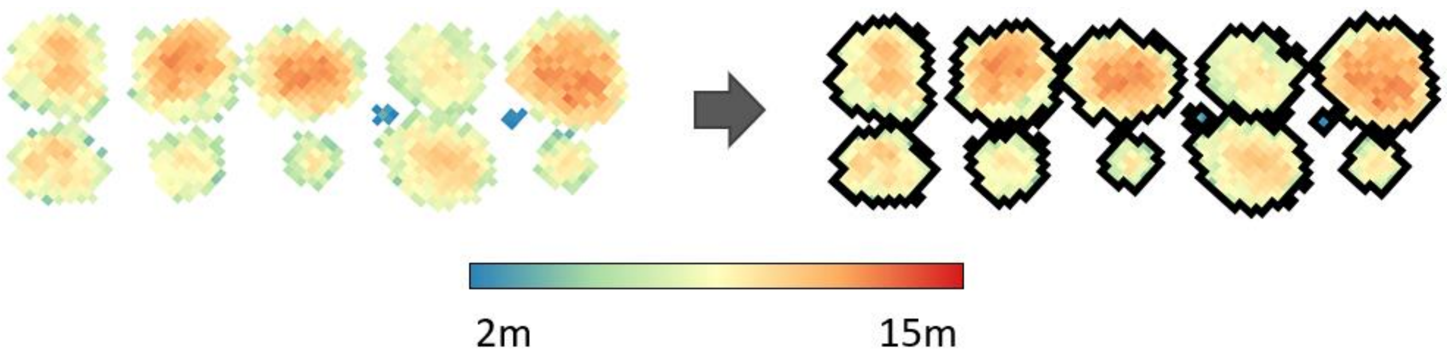
DEM *Segmented DEM*



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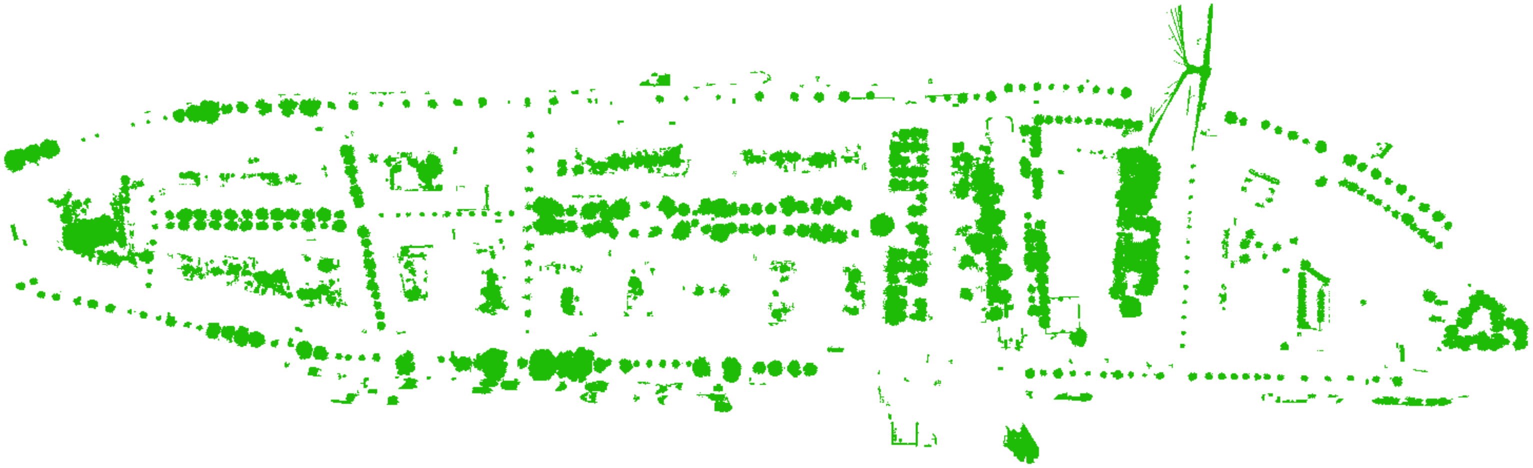

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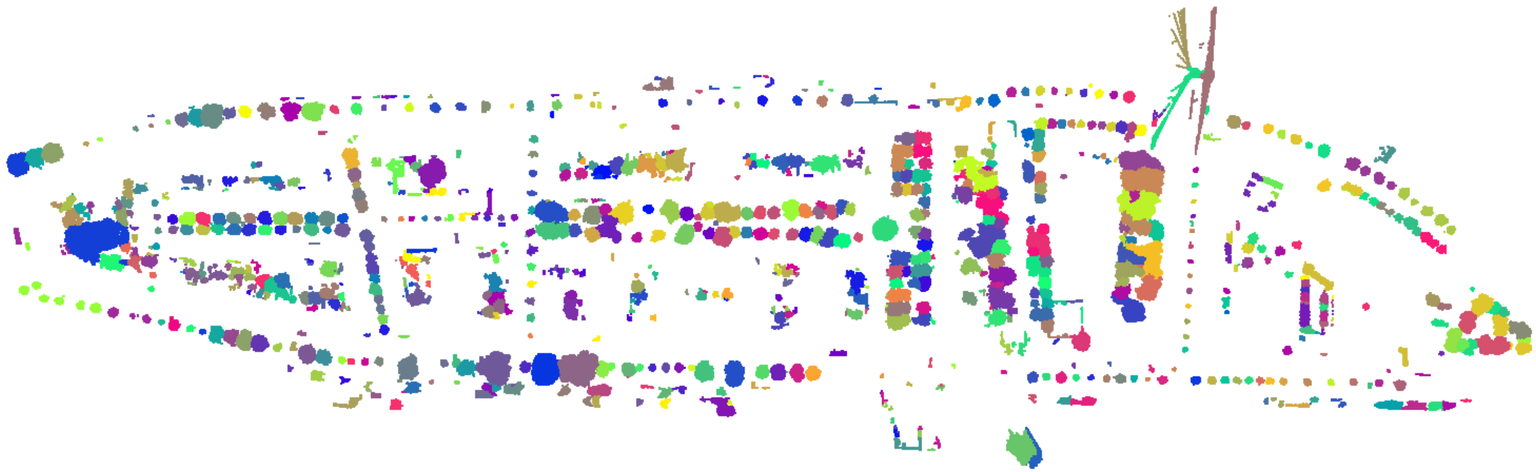

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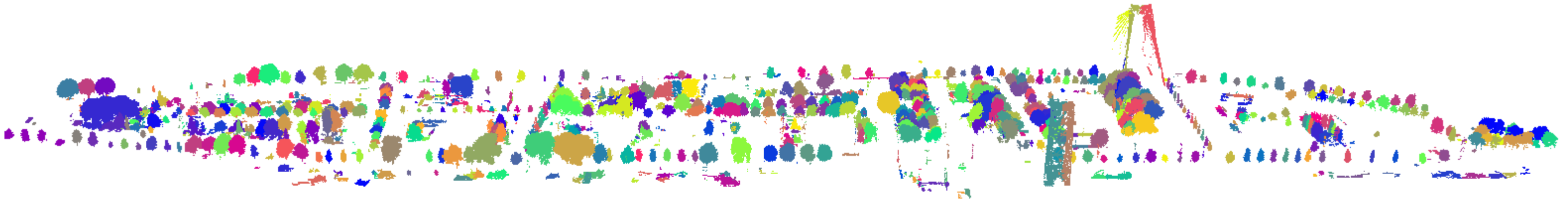

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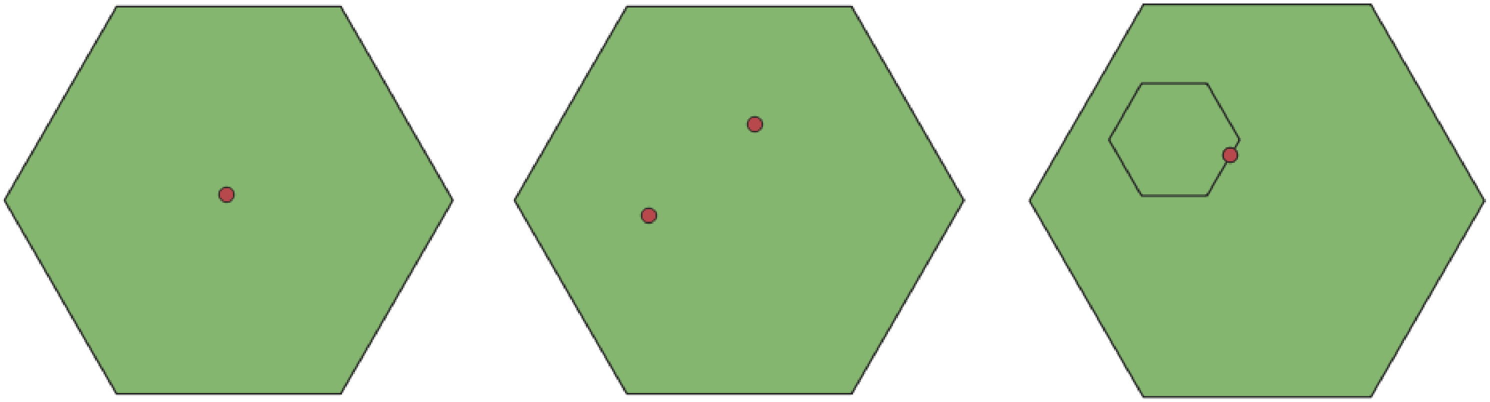

Good ***Under*** ***Over***

Segmentation

DEM resolution	Underseg.	Overseg.	Good segmentation
0.25m	4.3%	20.6%	75.0%
0.50m	10.6%	8.6%	80.8%
0.75m	12.5%	4.0%	83.6%
1.00m	13.3%	3.4%	83.2%
1.25m	17.3%	1.2%	81.4%
1.50m	18.5%	2.3%	79.3%

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Threshold	Trees recognized	Underseg.	Overseg.	Good segmentation
1.00m	91.6%	9.1%	7.7%	83.2%
1.10m	89.7%	10.4%	6.7%	82.9%
1.20m	88.0%	11.2%	5.7%	83.1%
1.30m	85.7%	12.3%	4.5%	83.2%
1.40m	84.5%	12.5%	3.7%	83.8%
1.50m	82.8%	12.5%	4.0%	83.6%
1.60m	81.8%	12.6%	3.2%	84.2%
1.70m	81.8%	12.6%	3.2%	84.2%
1.80m	81.3%	13.3%	3.5%	83.2%
1.90m	80.6%	13.1%	2.2%	84.6%
2.00m	79.9%	13.5%	2.2%	84.2%

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Threshold	Trees recognized	Underseg.	Overseg.	Good segmentation
1.00m	91.6%	9.1%	7.7%	83.2%
1.10m	89.7%	10.4%	6.7%	82.9%
1.20m	88.0%	11.2%	5.7%	83.1%
1.30m	85.7%	12.3%	4.5%	83.2%
1.40m	84.5%	12.5%	3.7%	83.8%
1.50m	82.8%	12.5%	4.0%	83.6%
1.60m	81.8%	12.6%	3.2%	84.2%
1.70m	81.8%	12.6%	3.2%	84.2%
1.80m	81.3%	13.3%	3.5%	83.2%
1.90m	80.6%	13.1%	2.2%	84.6%
2.00m	79.9%	13.5%	2.2%	84.2%

*84.5% * 83.8% ≈ 70%*

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Data Cleaning

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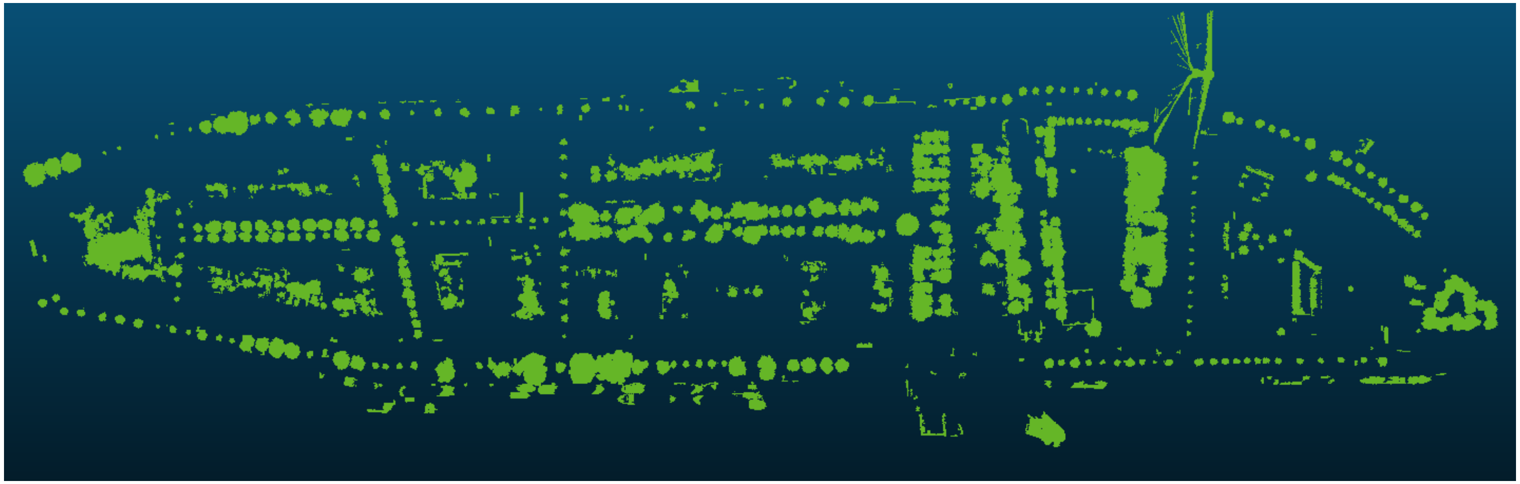

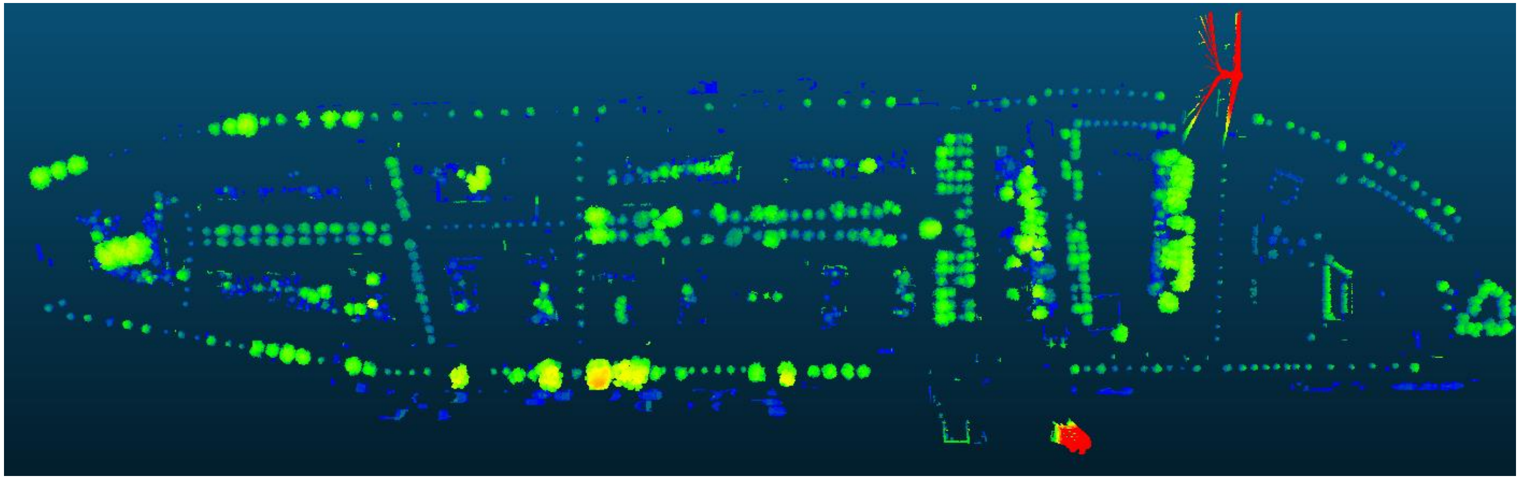

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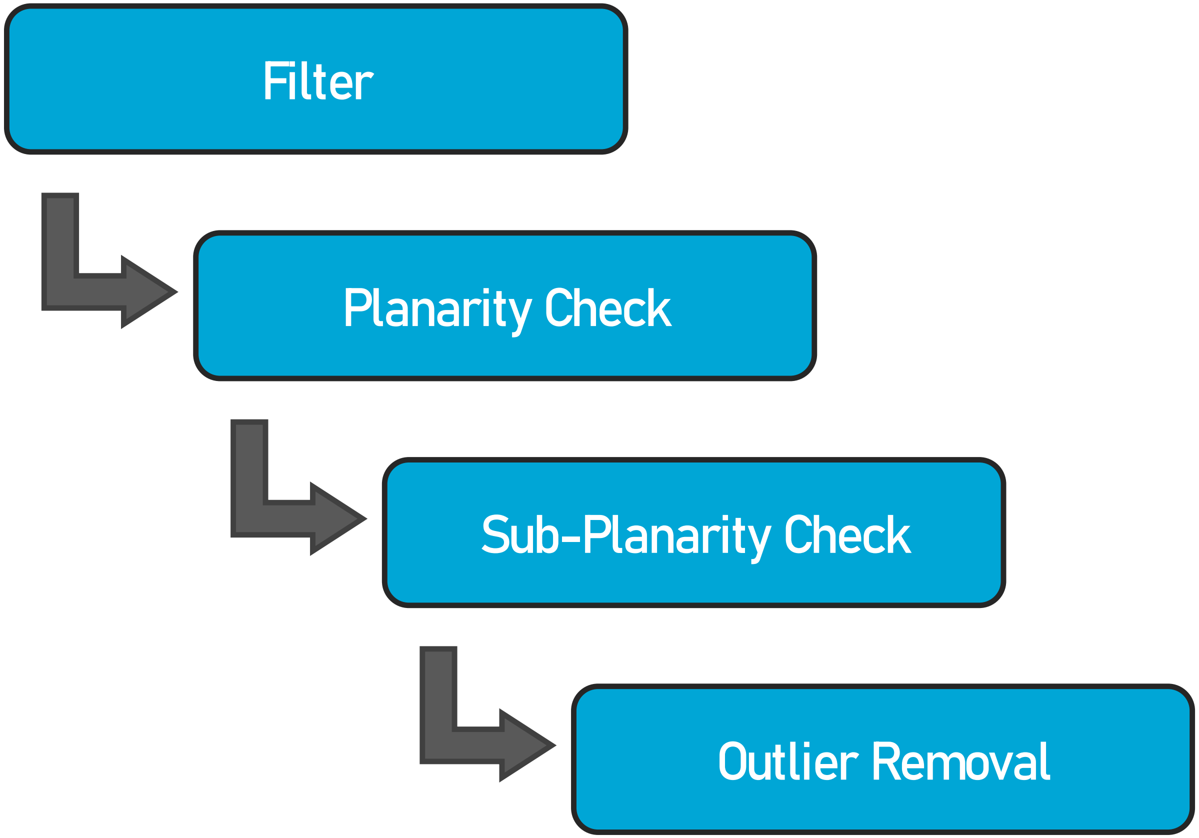
Data Cleaning



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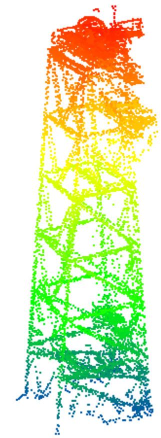
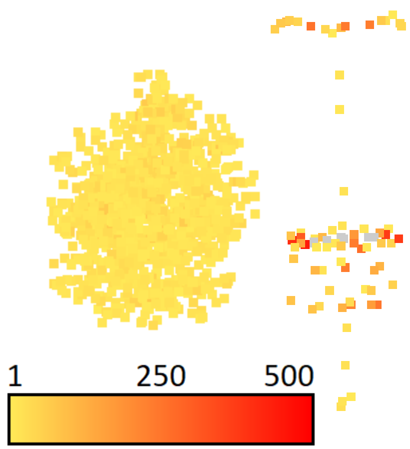
Filter

Rules:

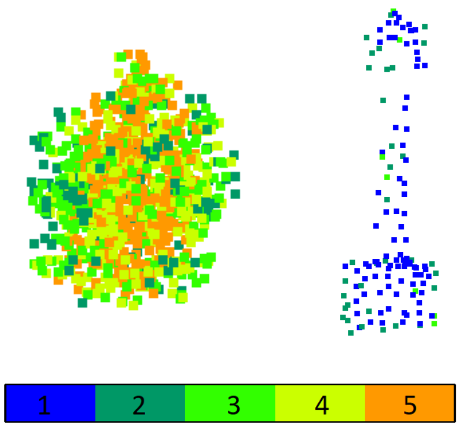
- A segment needs to consist of at least 50 points
- A segment's average intensity value needs to be below 100
- A segment's average number of returns should be above 1.5
- A segment's maximum height is 50m




Max height: 70m



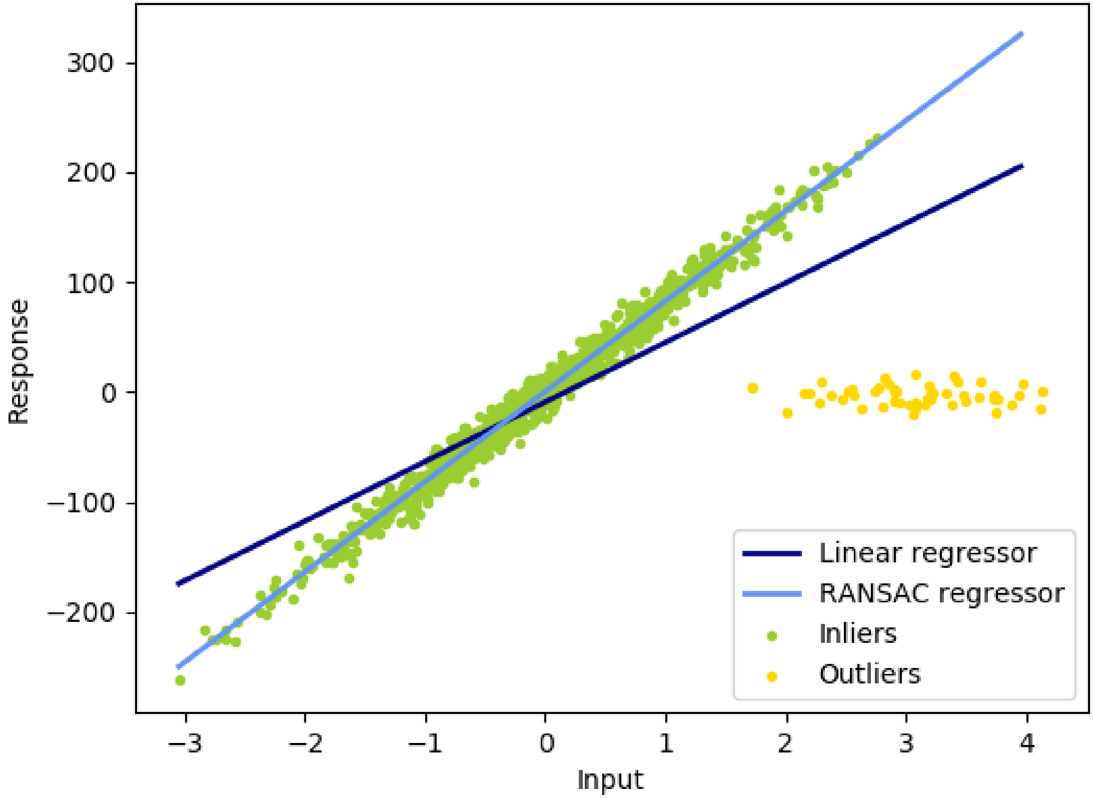
Avg. Intensity: 1460



Avg. nr of returns: 1.3

Planarity Check

Random Sample Consensus (RANSAC)



2D RANSAC (Pedregosa et Al., 2008)

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Planarity Check

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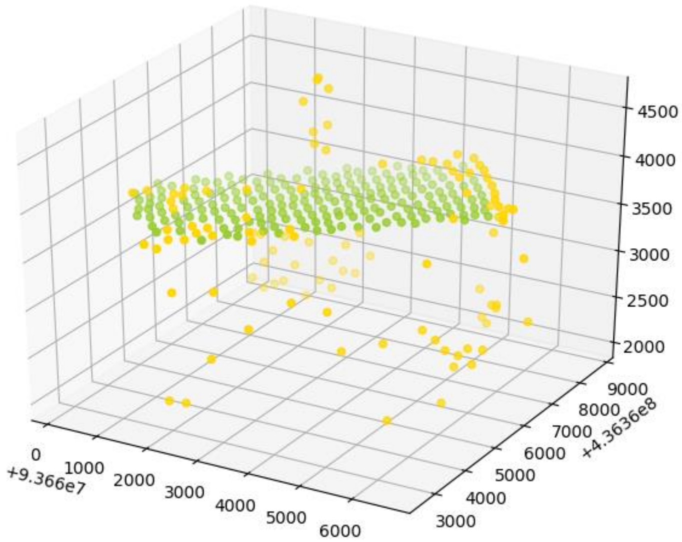
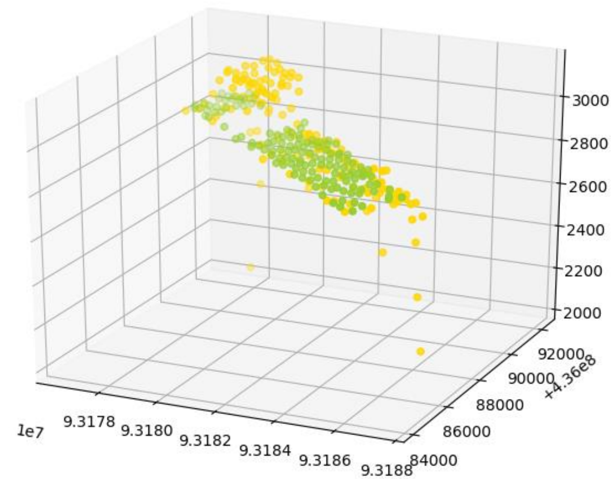
Remove:





Distance < 100mm

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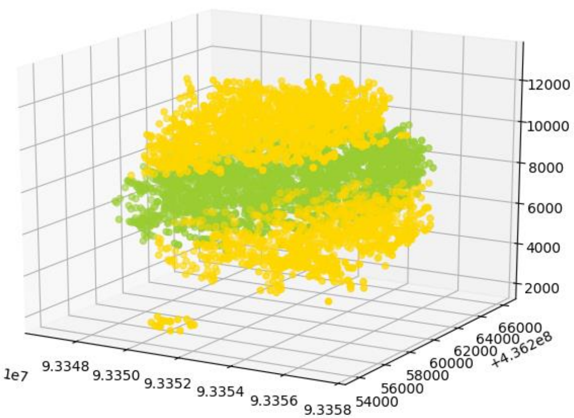
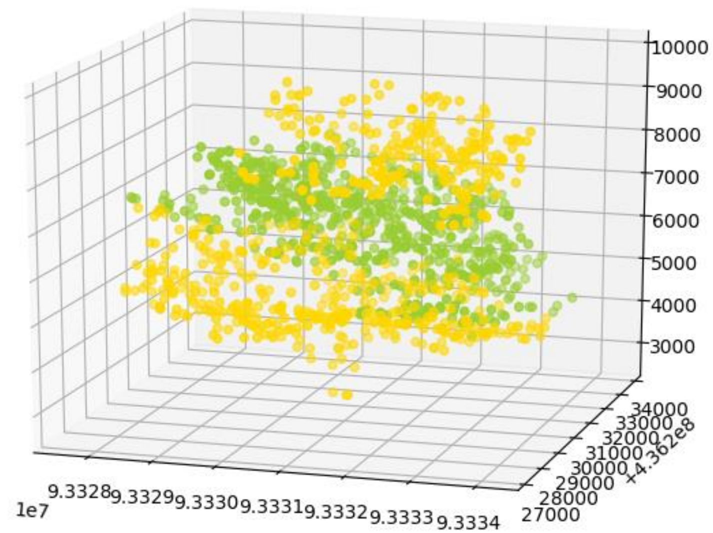
Do not remove





Distance > 100mm

Sub-Planarity Check

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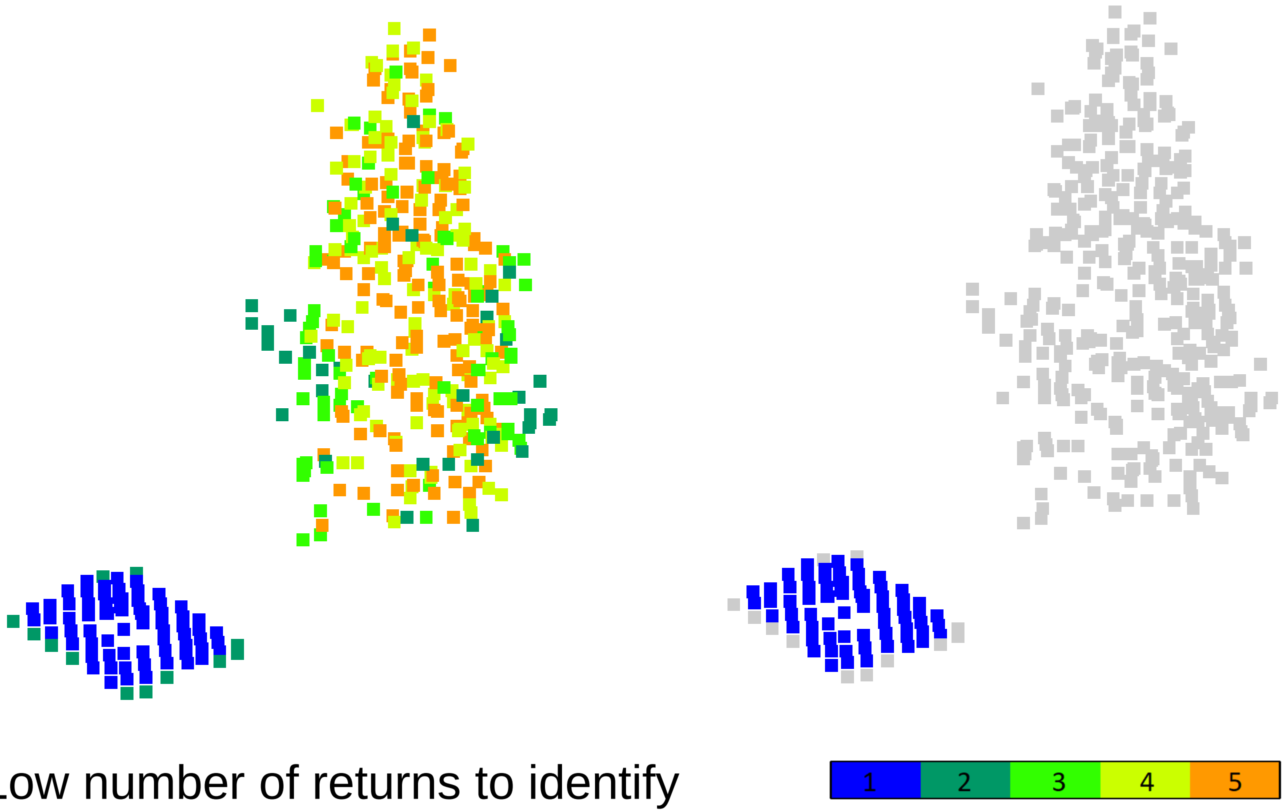
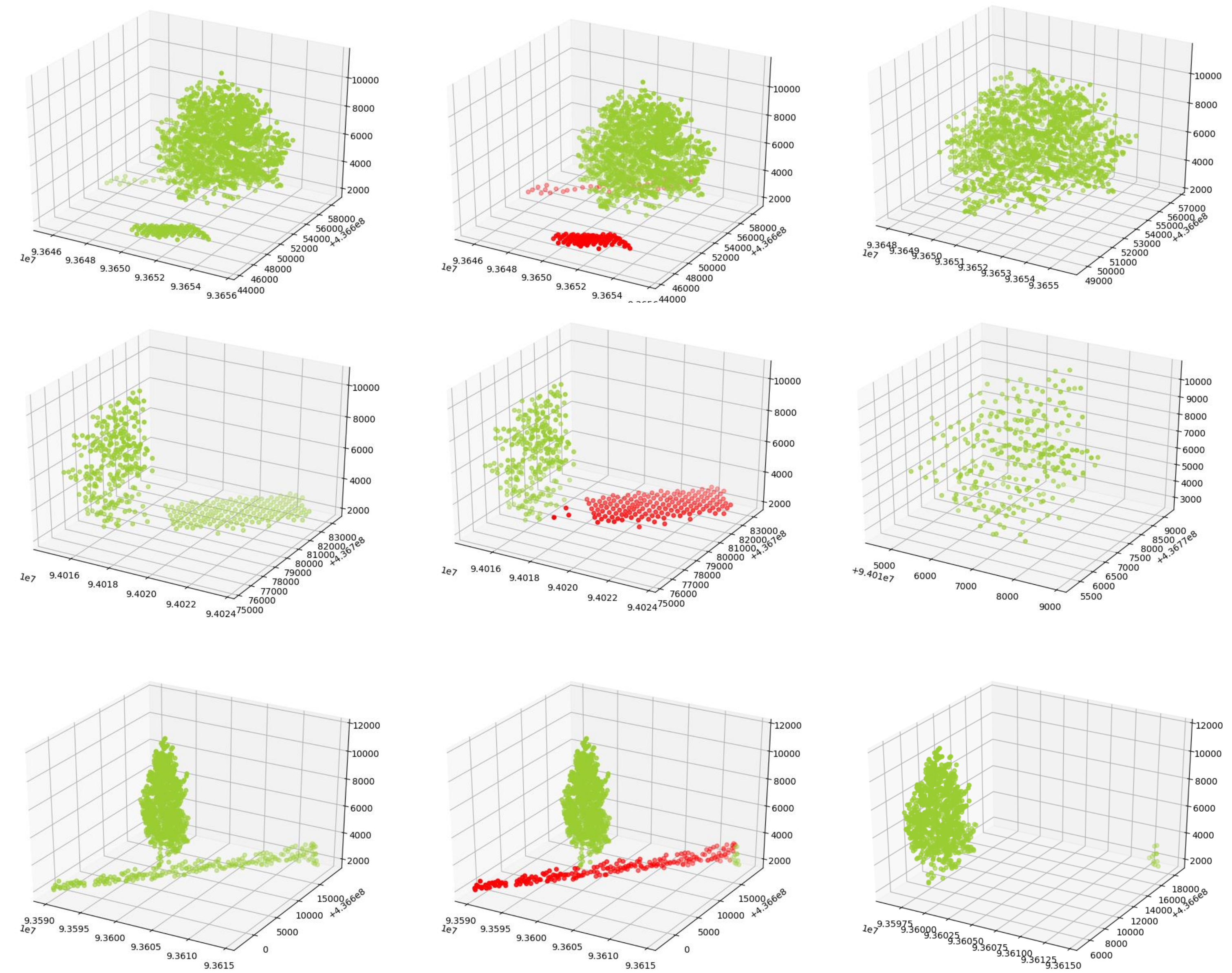


Low number of returns to identify planes within segments

Sub-Planarity Check



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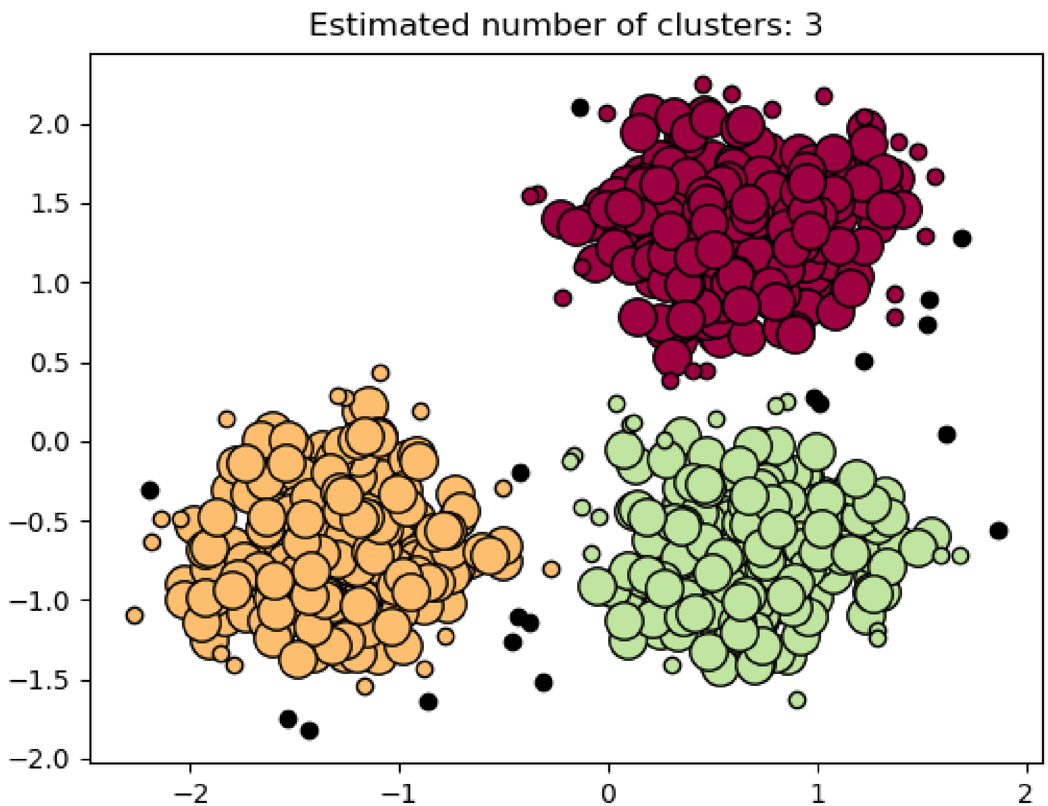
Outlier Removal

Density-Based Spatial Clustering of Applications with Noise (DBSCAN)



DBSCAN (Pedregosa et Al., 2008)

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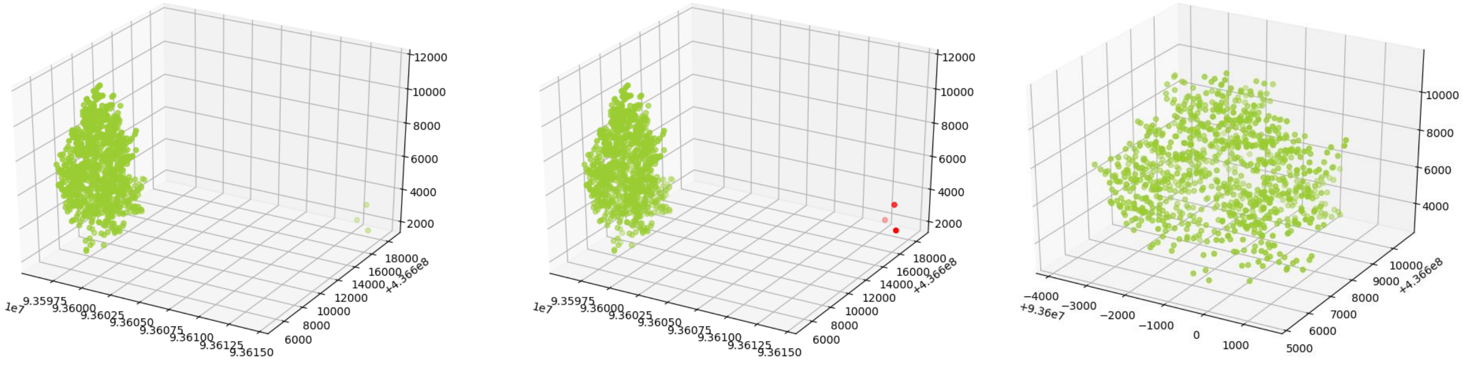
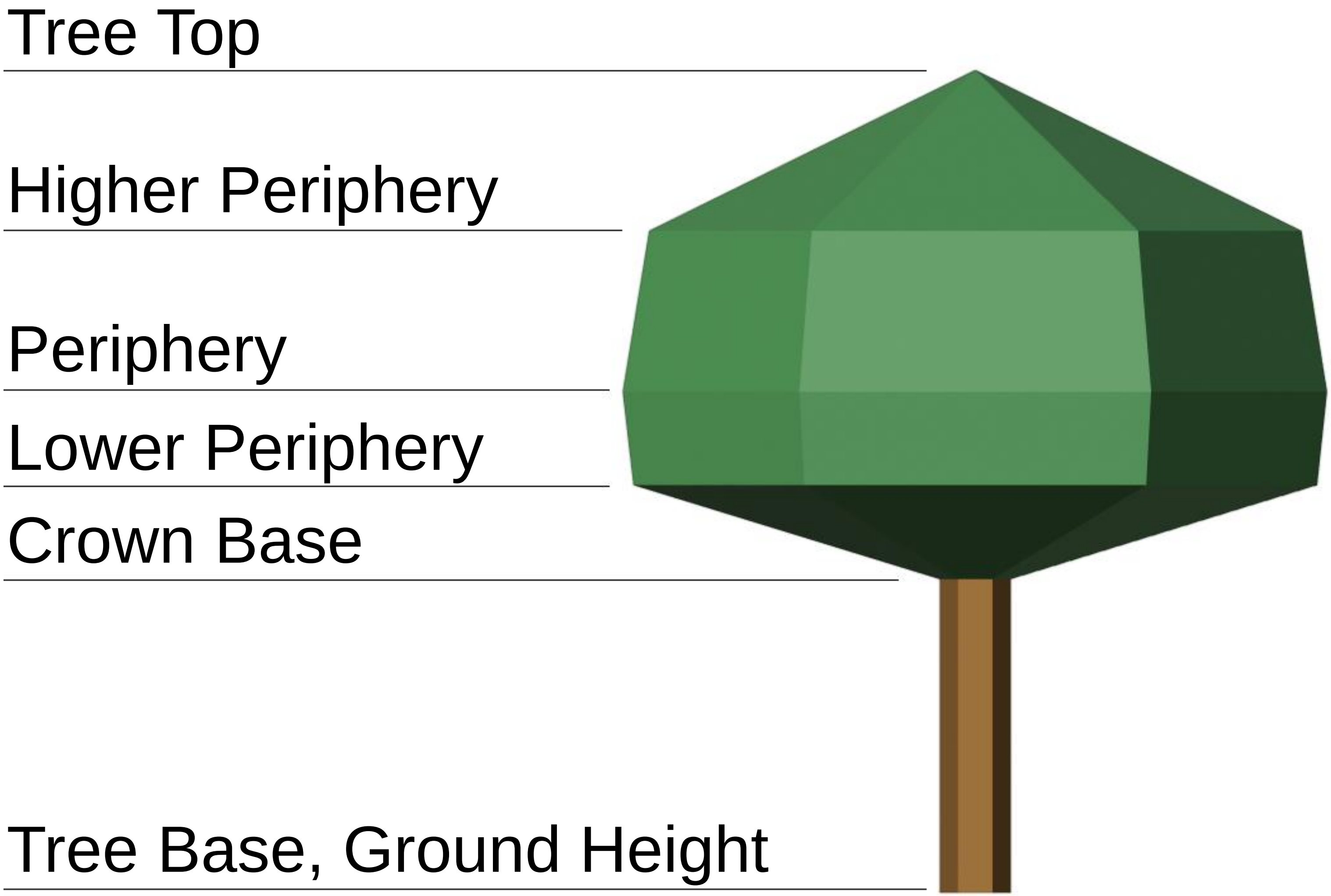


Modelling Parameters



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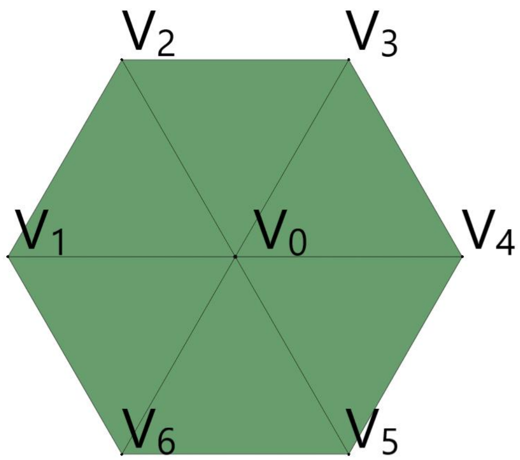
Modelling

Vertex	X	Y	Z
v0	$x = a$	$x = b$	$x = c$
v1	$x = a - r$	$x = b$	$x = c$
v2	$x = a - cos(60) * r$	$x = b + sin(60) * r$	$x = c$
v3	$x = a + cos(60) * r$	$x = b + sin(60) * r$	$x = c$
v4	$x = a + r$	$x = b$	$x = c$
v5	$x = a + cos(60) * r$	$x = b - sin(60) * r$	$x = c$
v6	$x = a - cos(60) * r$	$x = b - sin(60) * r$	$x = c$



Modelling

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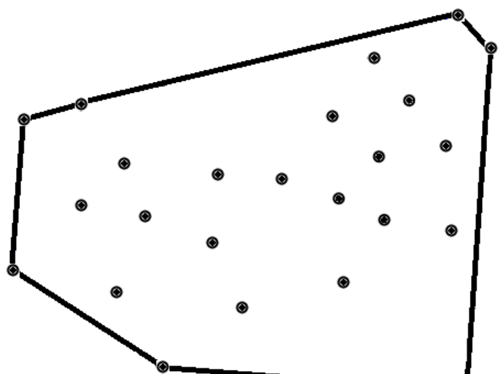
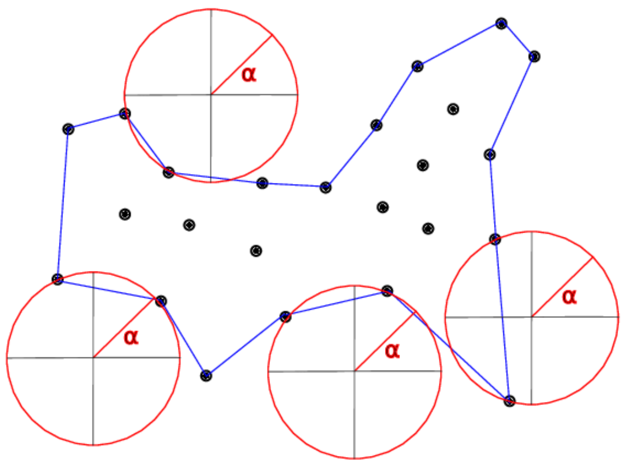


Convex Hull



Alpha Shape

Alpha shape (Eich et Al., 2008)

Modelling

LOD0 *LOD1* *LOD2* *LOD3.0* *LOD3.1*

Type Classification

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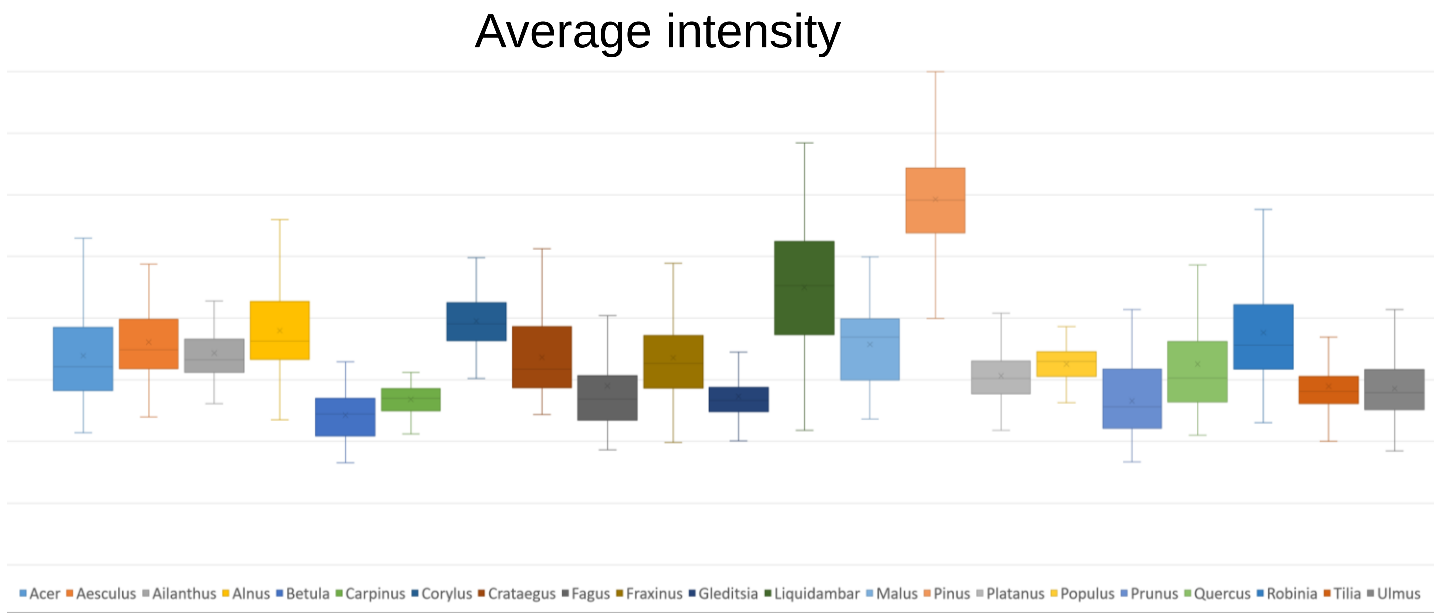
Type Classification

Genera



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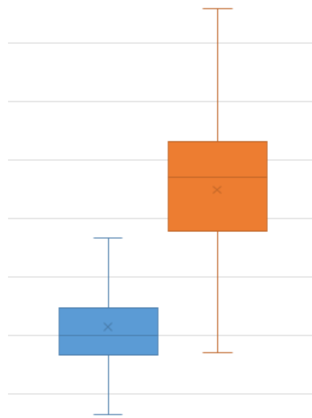
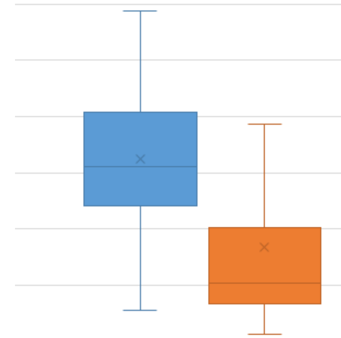
Type Classification

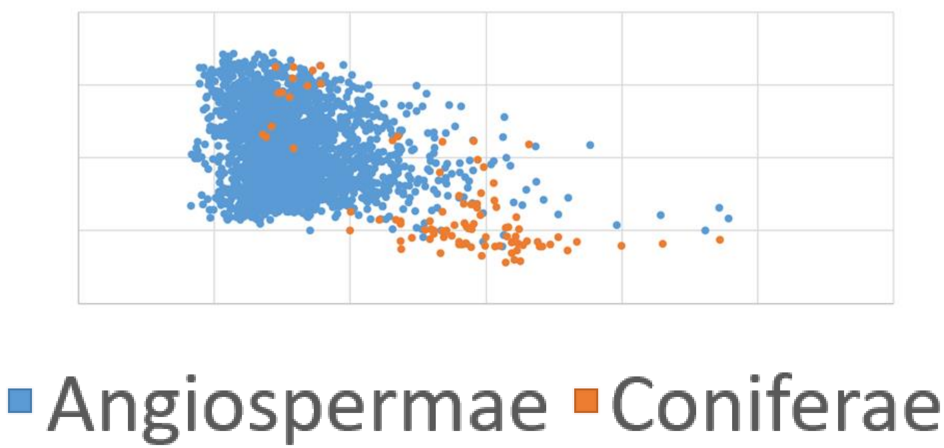
Clades

Average intensity



Average nr of returns





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Good examples

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Remaining inaccuracies

Outliers

Under-segmentation

Misclassification

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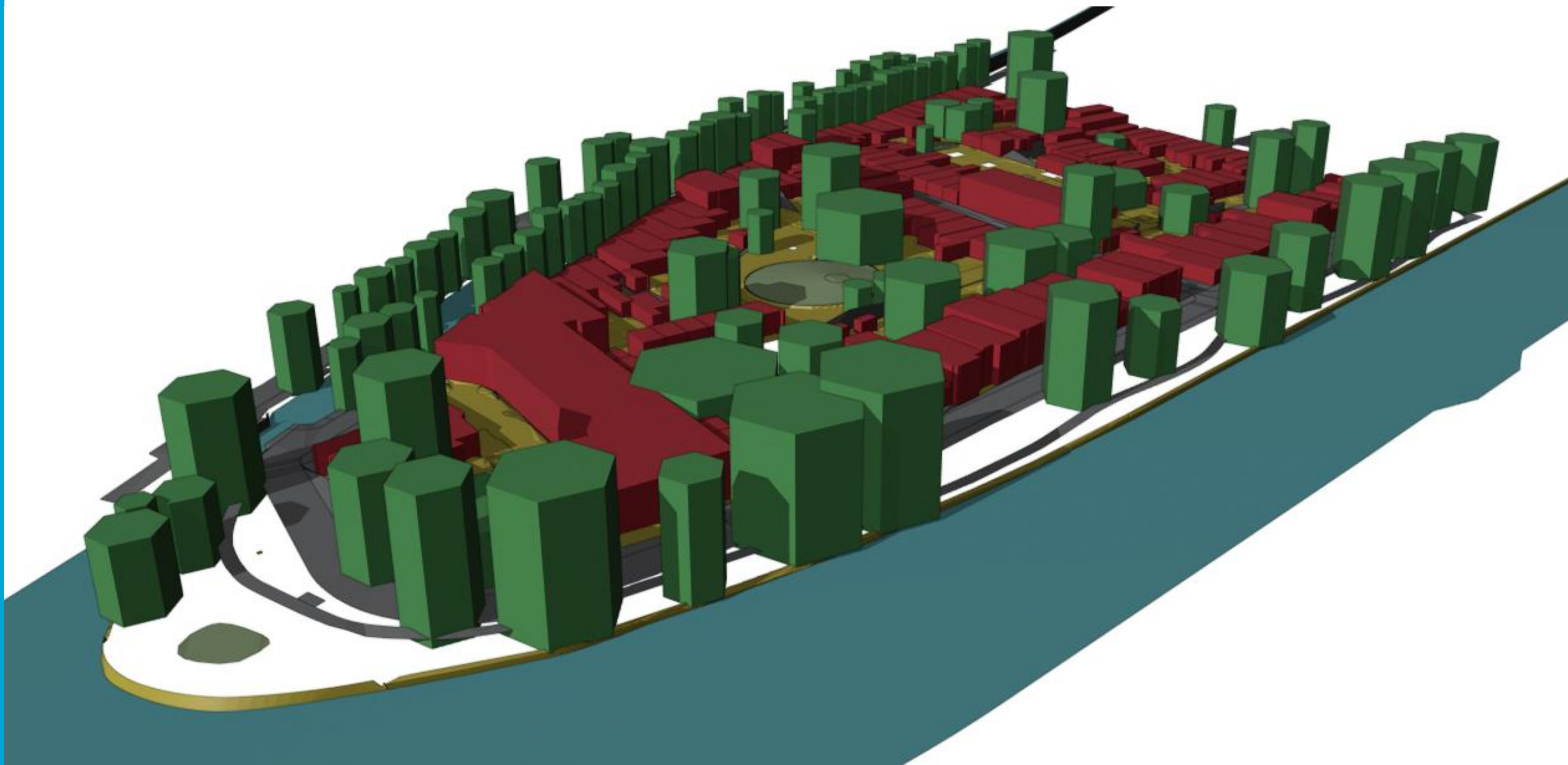

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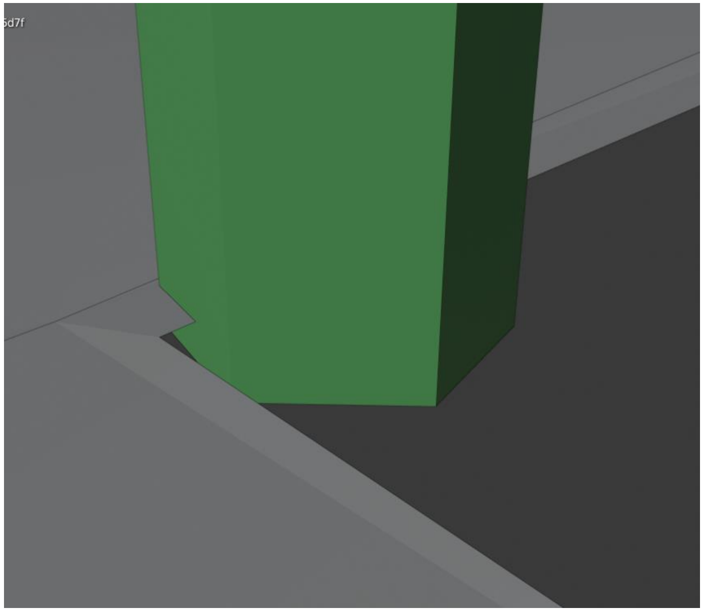
Penetrating the irregular ground

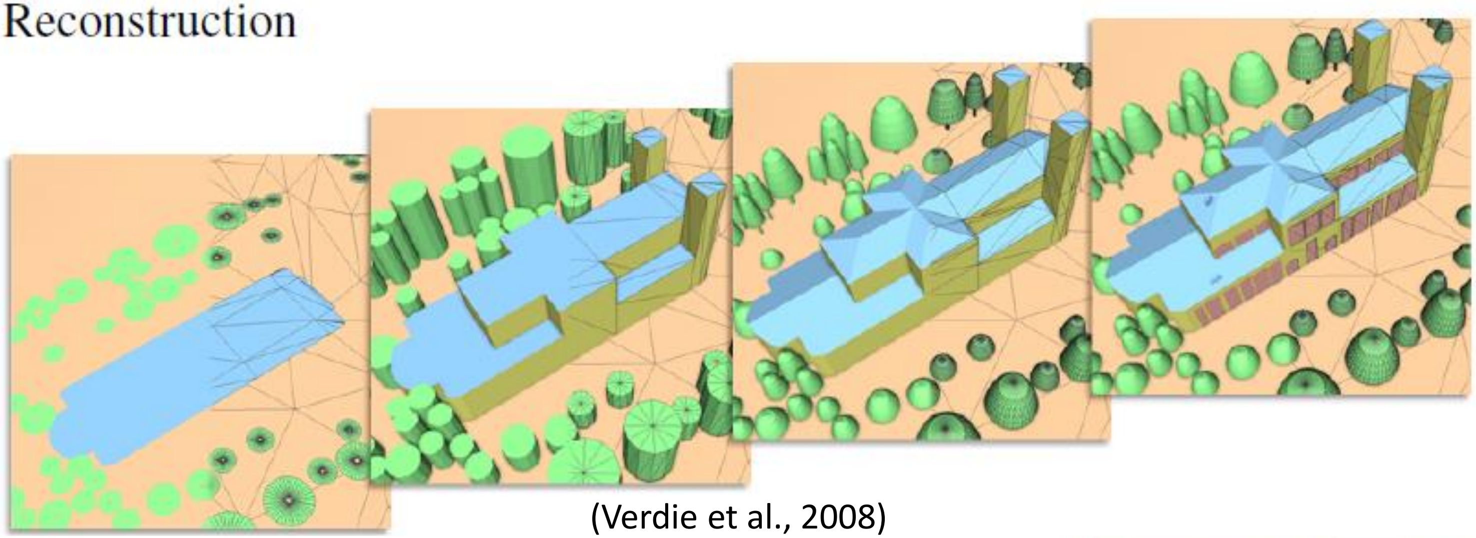


Open Gap

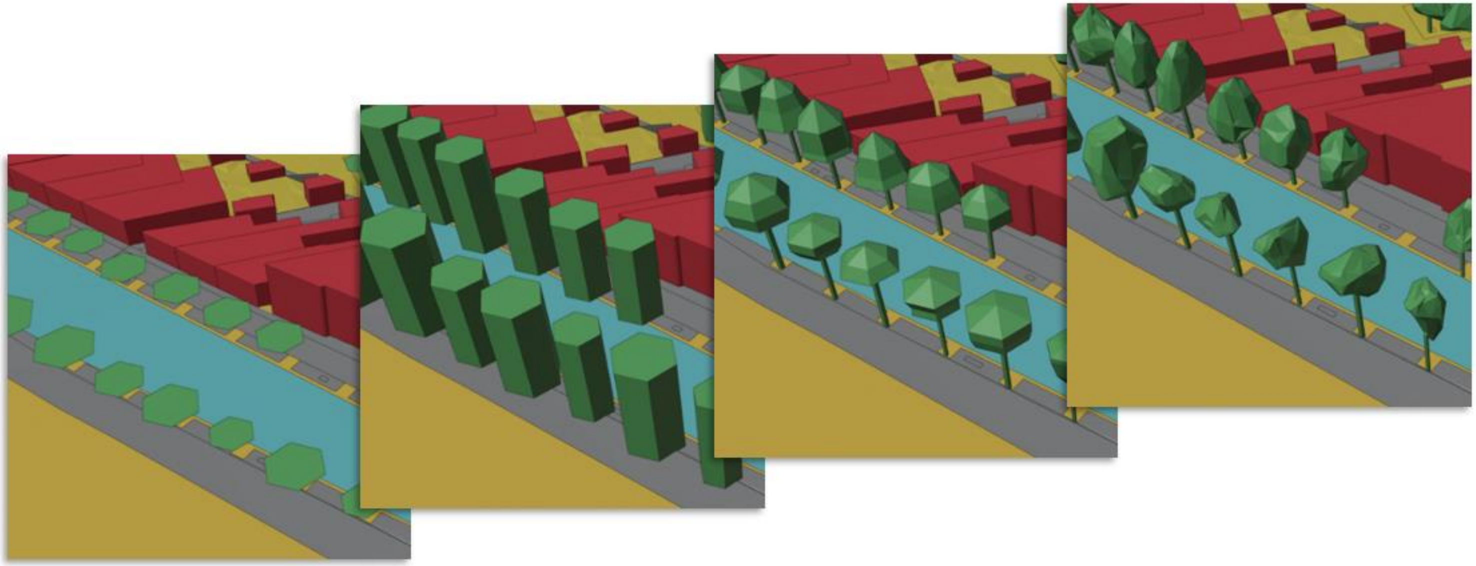
Penetration

Comparison

Reconstruction



(Verdie et al., 2008)



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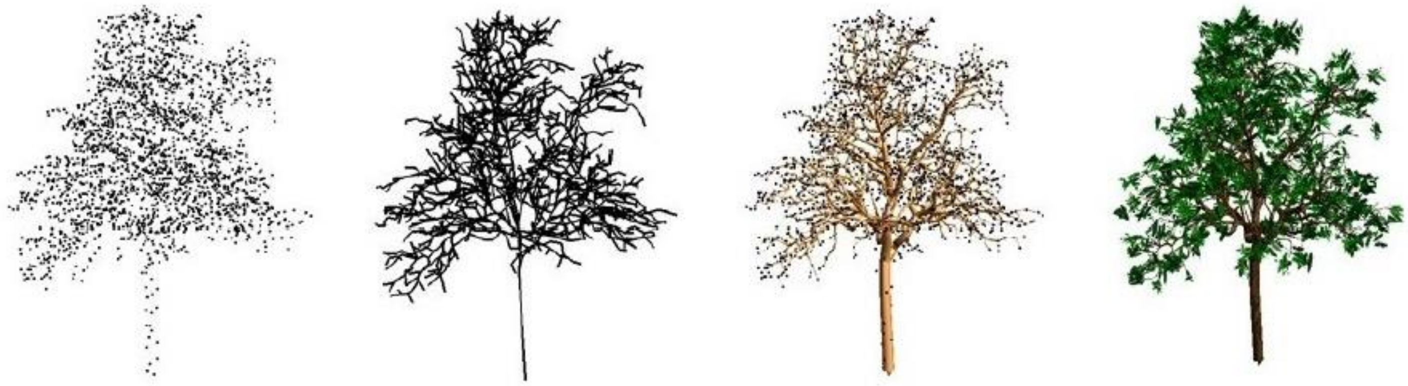
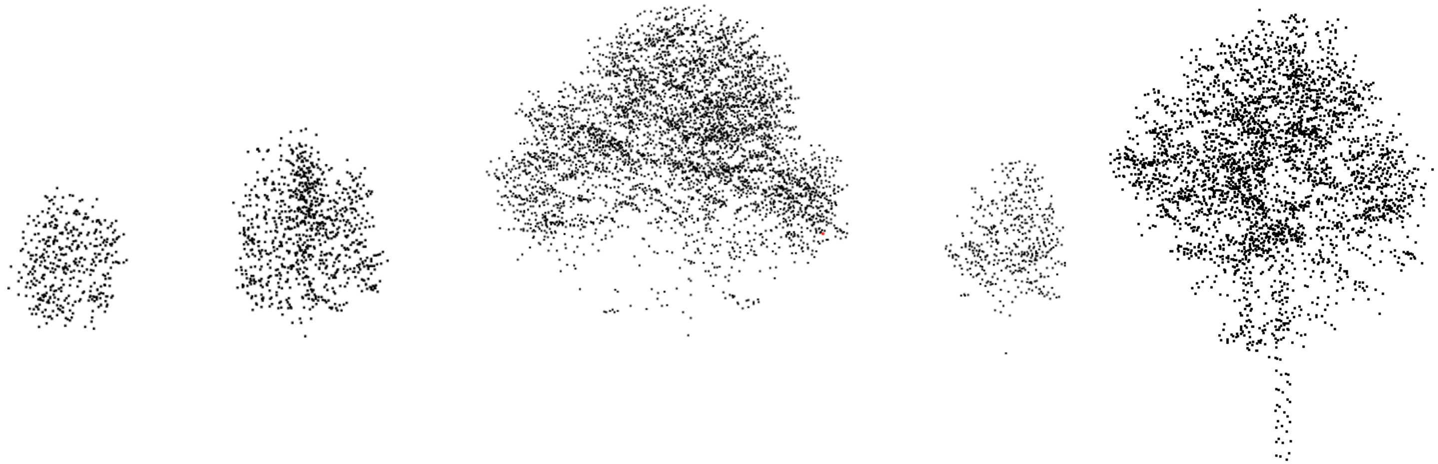


(Du, 2019)



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Conclusions

How can 3D tree models at varying Levels of Detail be automatically constructed from airborne LiDAR point cloud data?

- This implementation shows how
- 85% trees recognized
- 70% is modelled correctly
- Multiple LODs supported

How can a final implementation be made to fit into the 3dfier pipeline?

- For simple visualization, it fits
- For a seamless fit, more work needs to be done

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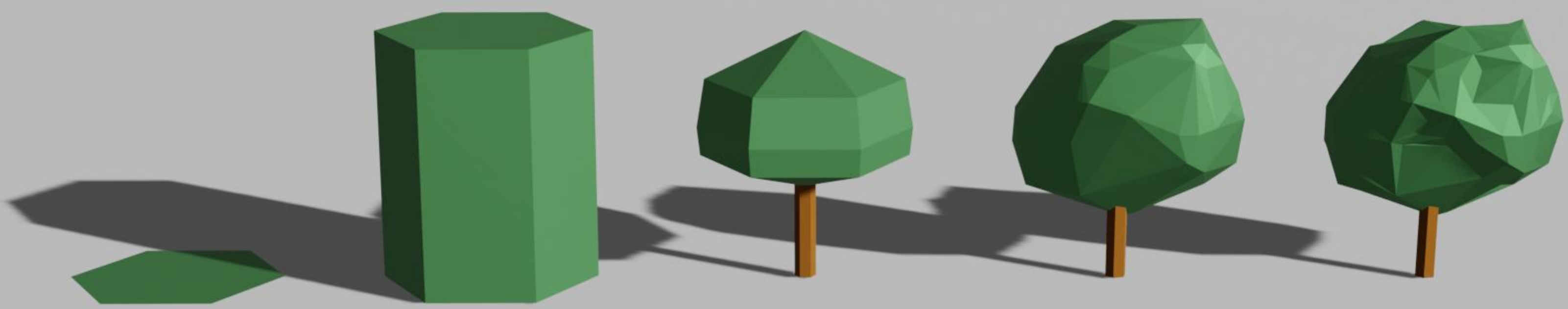
Future Work

- Ground Truth for AHN3
- Post-Segmentation improvements
- Tree trunks
- Seamless integration 3dfier

Automatic construction of 3D tree models from airborne LiDAR data in multiple levels of detail



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