

From Points to Prints

Lastig Internal Seminar

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Context

Context	1
Roof edge points	4
Creation of the roofprints	8
Footprint points	20
Creation of the footprints	21

Roofprint vs. footprint

	Roofprint	Footprint
Defined by	Roof	Façades
Comes from	Aerial data (images, ALS)	Terrain measurements (TLS, MLS)
Used for	3D modelling, solar potential	Tax estimation, energy consumption

Table 1: Comparison between roofprints and footprints

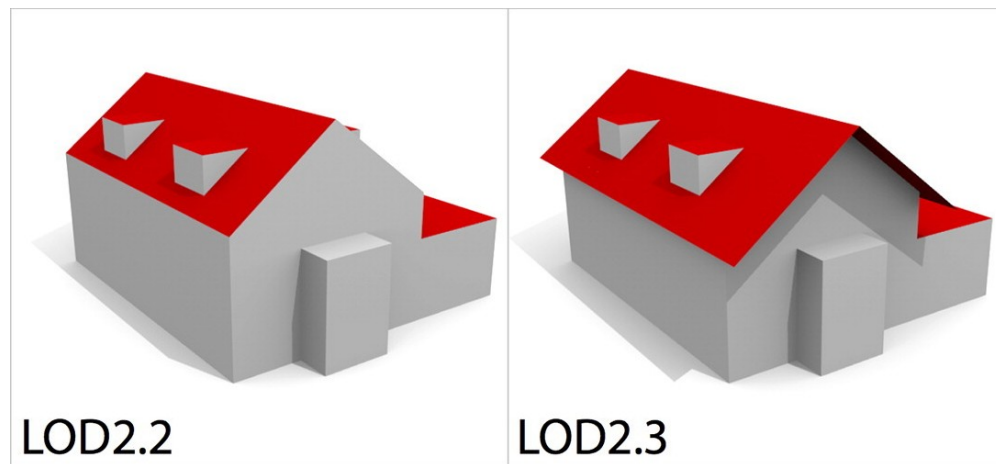


Figure 1: Part of the visual definition of buildings Level of Detail (LoD) containing LoD 2.2 and 2.3 (Biljecki et al., 2016) .

Strengths and weaknesses of BD TOPO

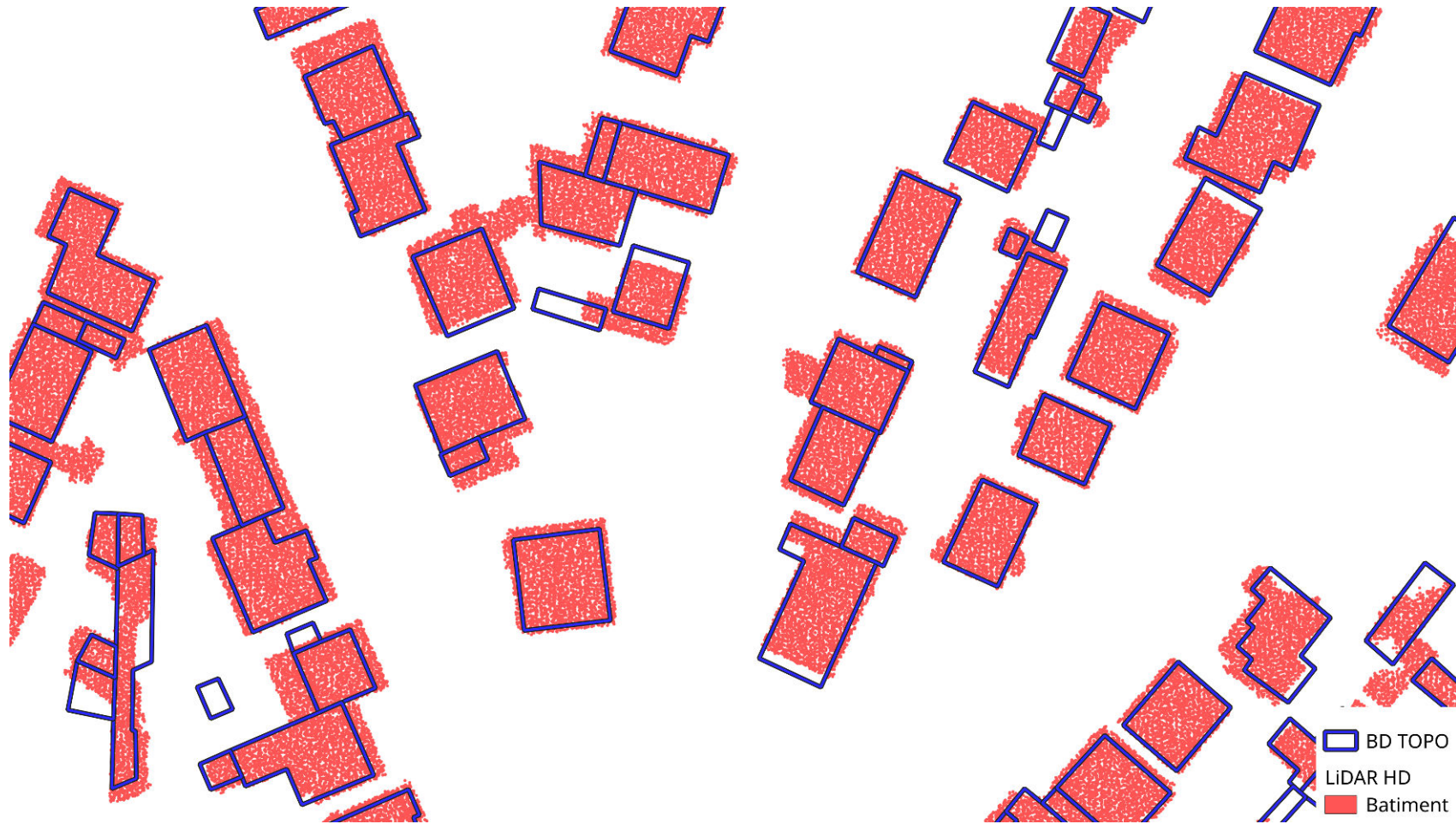


Figure 2: BD TOPO buildings are most of the time footprints, and often shifted.

*Generate for each building a **roofprint** and a **footprint** coherent with that roofprint, and by doing so estimate the **roof overhangs**.*

Overview of the methodology

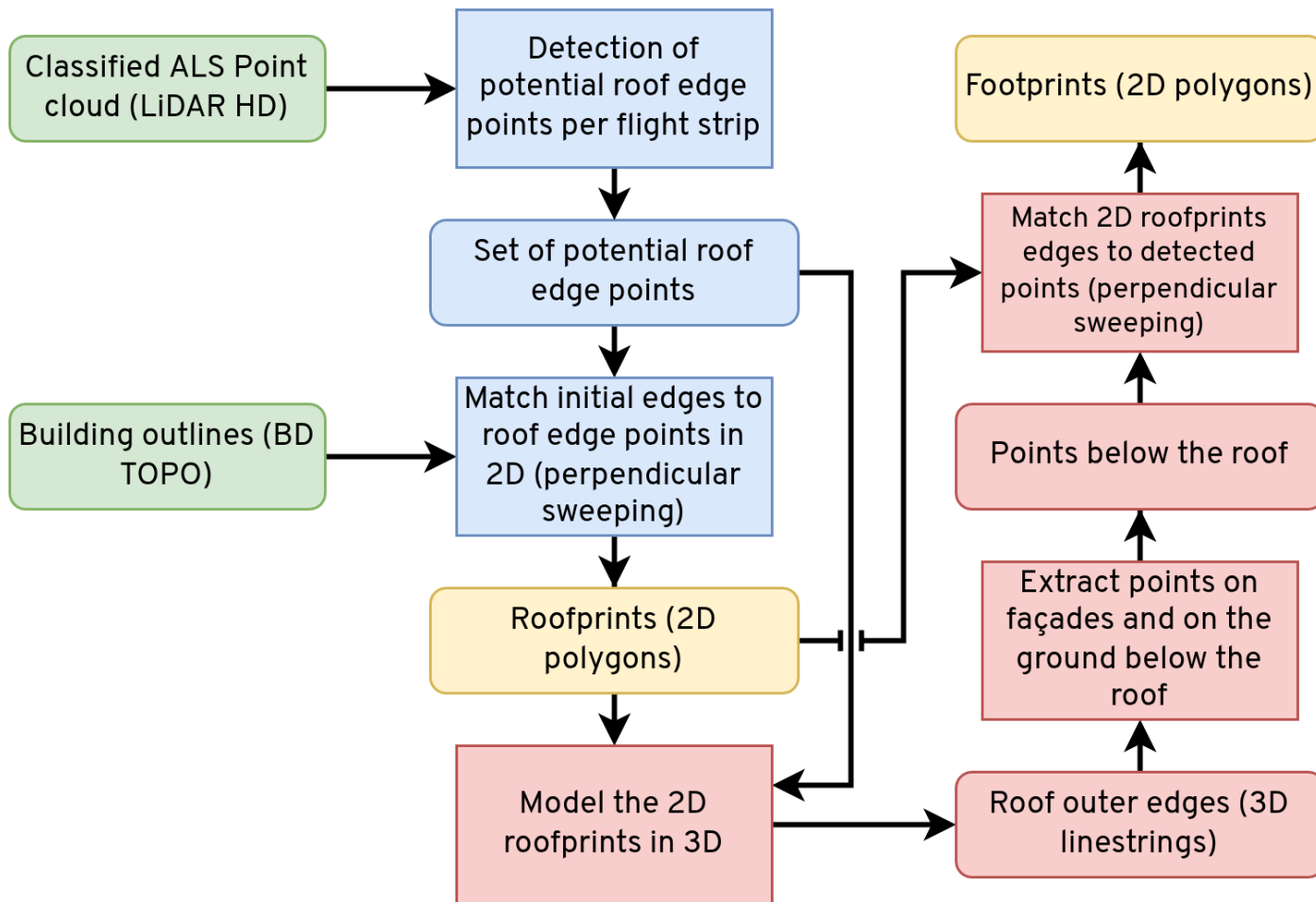


Figure 3: Overview of the pipeline.

Roof edge points

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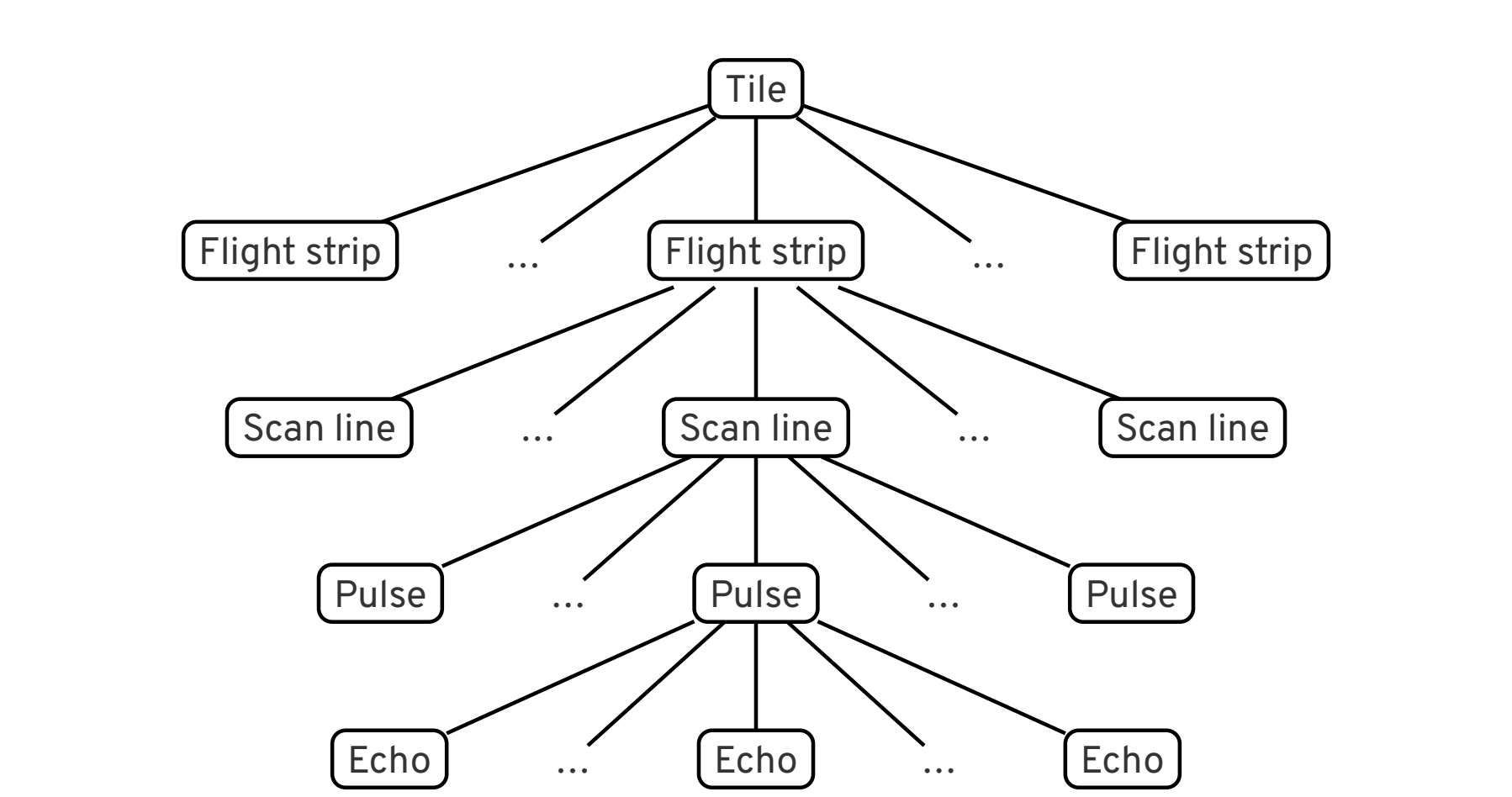
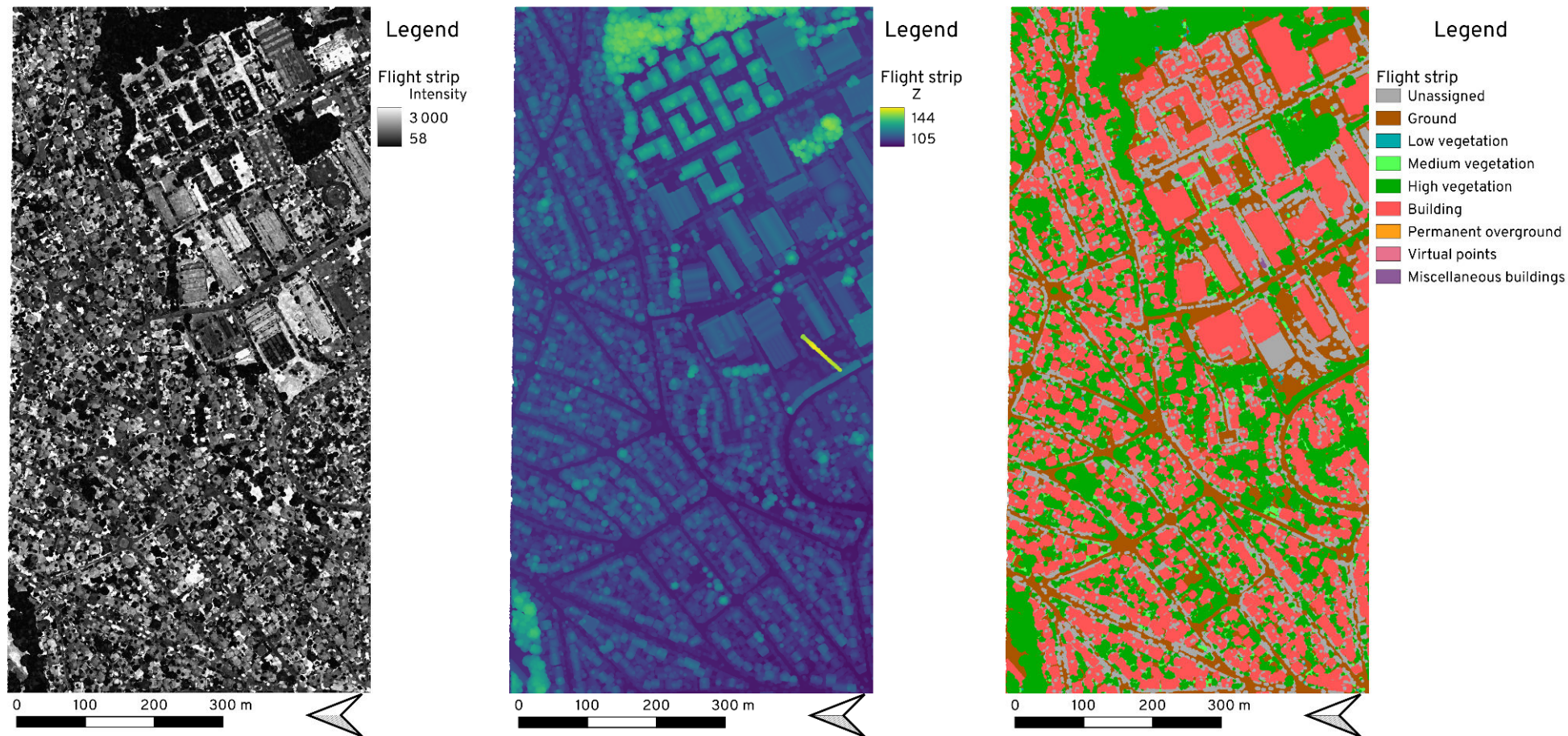


Figure 4: Illustration of the structure of an ALS point cloud.

Point cloud topology



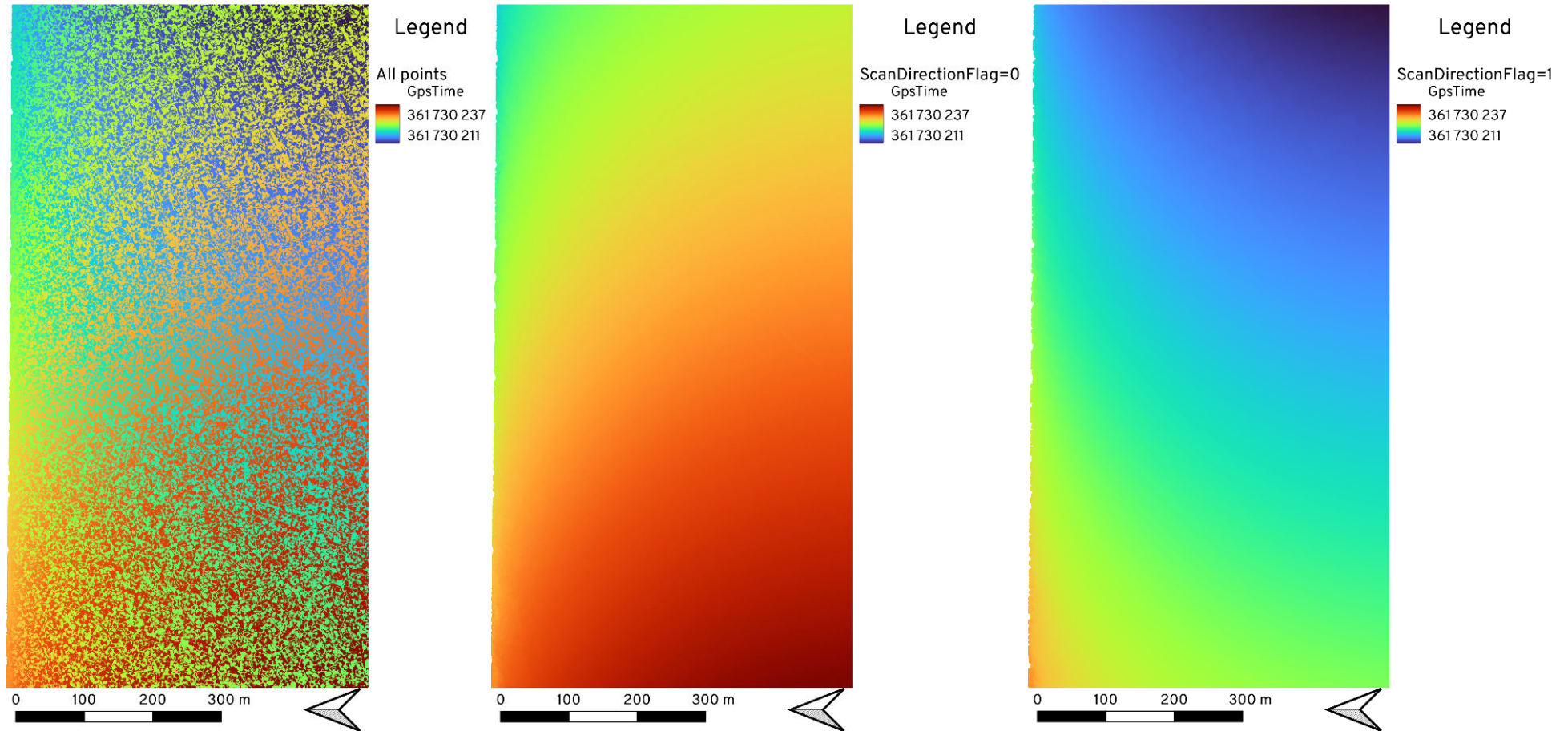
(a) Points coloured by intensity.

(b) Points coloured by height.

(c) Points coloured by classification.

Figure 5: Different visualizations of one flight strip.

Point cloud topology



(a) All points of one flight strip.

(b) Front scan line.

(c) Back scan line.

Figure 6: Visualization of the topology of the point cloud, with points coloured by their GPS Time.

Edge points detection

We use the **height differences between consecutive points** on the same scan line to identify points that are likely to be on the edges of roofs.

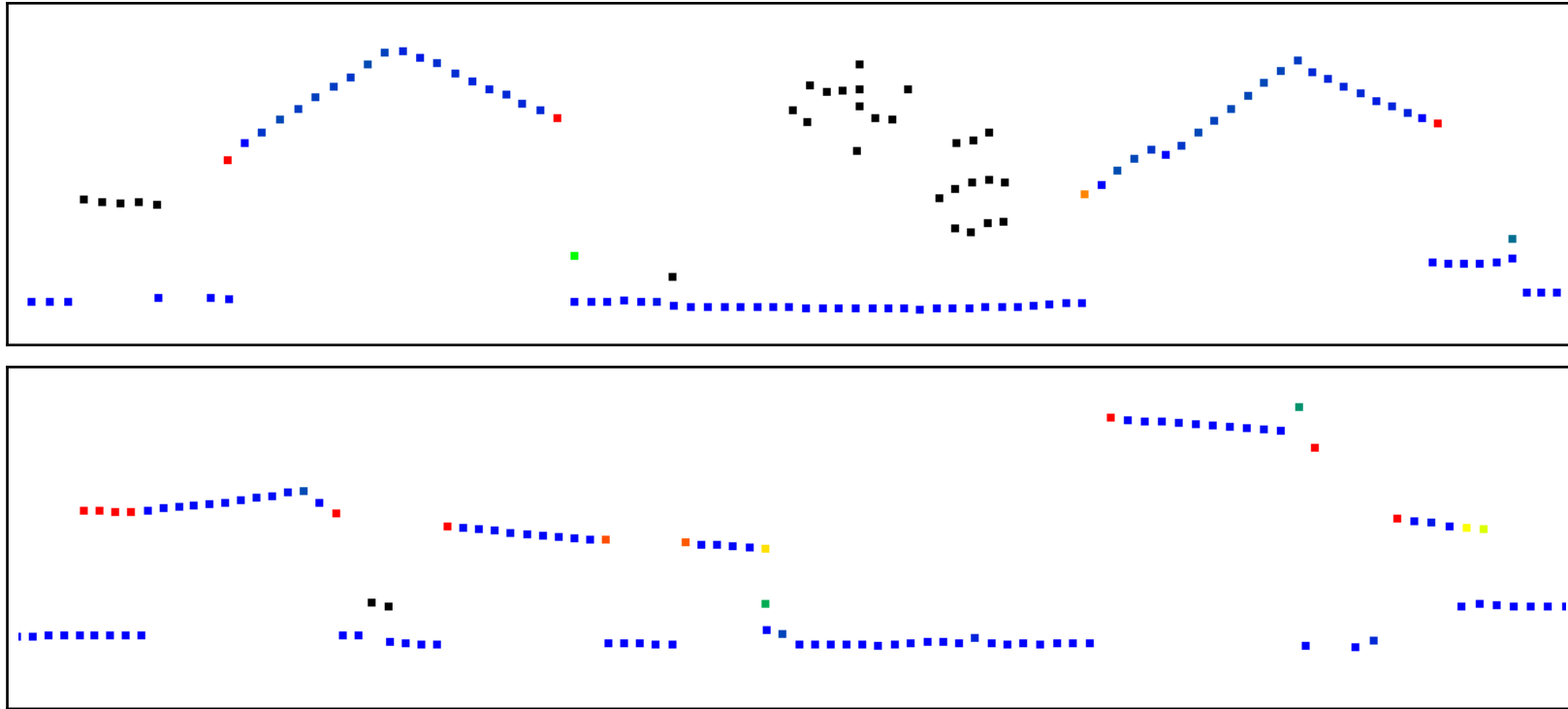


Figure 7: Two examples of the height differences obtained on a scan line. Black points are vegetation points, and for the other points the color represents the value of Δh , with blue-green-yellow-red from low to high values.

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Constraints over the movements

We modify the polygons by applying the following rules:

- **Never rotate an edge.**
- **Never flip an edge.**
- **Move overlapping edges together.**

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This ensures that we **preserve some topology** while keeping a **lot of freedom** for the edges to move.

However it is not perfect as it can **separate two points** that were initially at the same position.

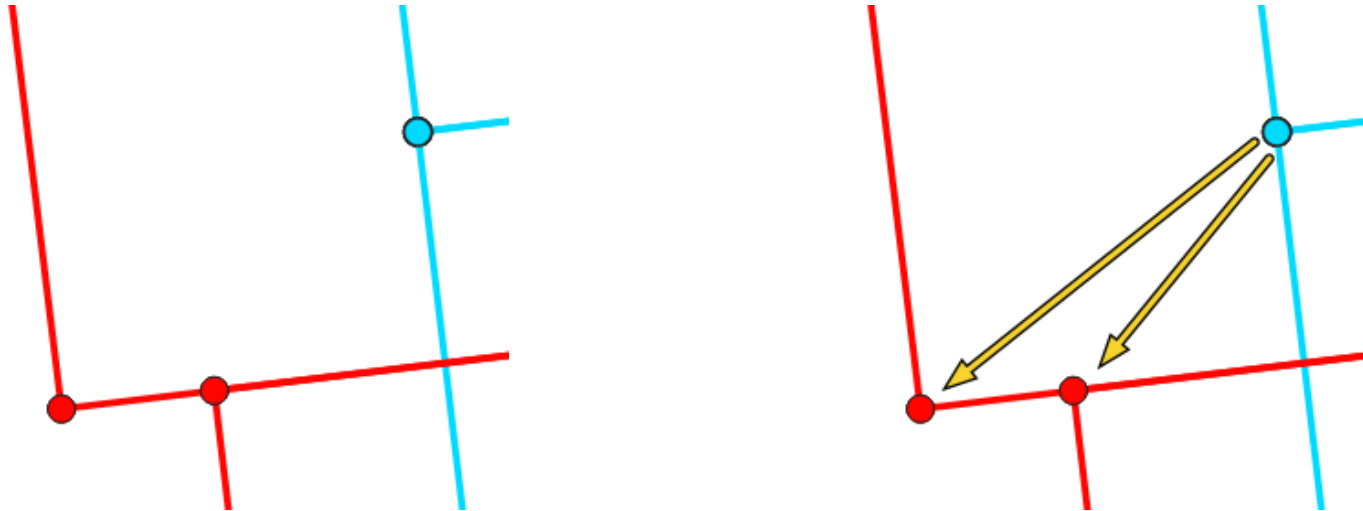


Figure 8: Two vertices at the exact same position become two distinct vertices at the boundary between two buildings.

Ideas behind the polygon deformation algorithm

- Edges are considered as **infinite lines**
- Edges are **translated perpendicularly** to themselves
- As soon as an edge is **flipped**, its **neighbours are translated one by one** until there is no flip

Illustrations of the polygon deformation algorithm

Illustrations can be viewed by following this link: https://alexandre-bry.github.io/MSc_Thesis-Report/slides_pages/2026_04_20-monthly.html

Criterion to score configurations

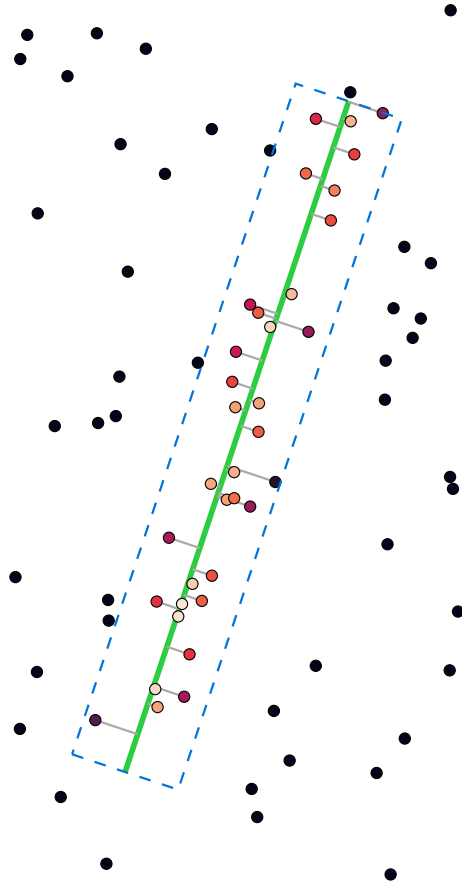


Figure 9: Illustration of the proximity score for an isolated edge.

Criterion to score configurations

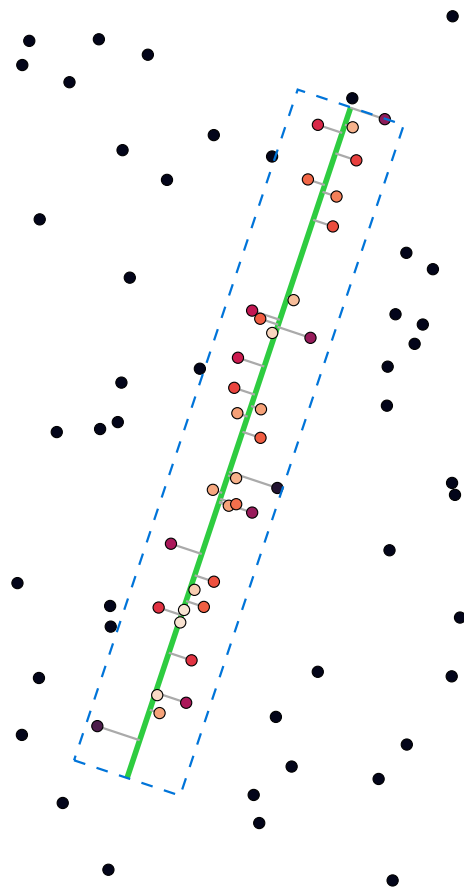


Figure 9: Illustration of the proximity score for an isolated edge.

We minimize the sum of an energy of all edges. The energy is defined with:

1. a **proximity term** → counts the number of points close to the edges
2. a **regularization term** → keeps edges close to their initial length

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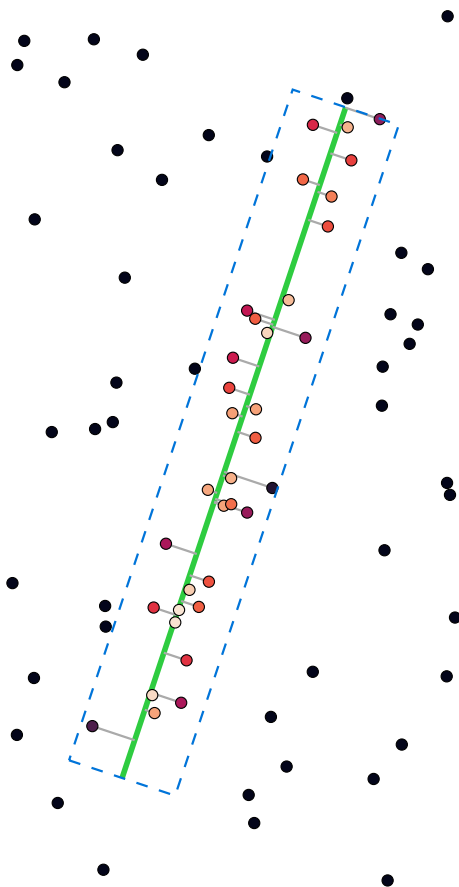


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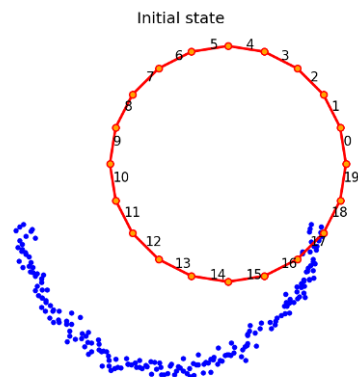
The proximity term contains:

1. a **weight** for each point,
2. a score based on the **distance** of the point to the edge
3. a score based on the **alignment** of the point with the edge

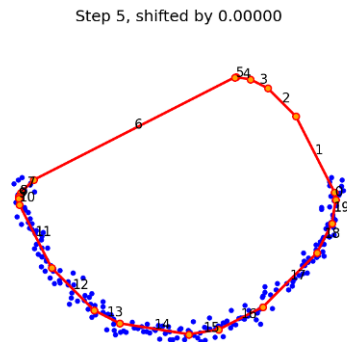
Illustrations of matching the edges to the points

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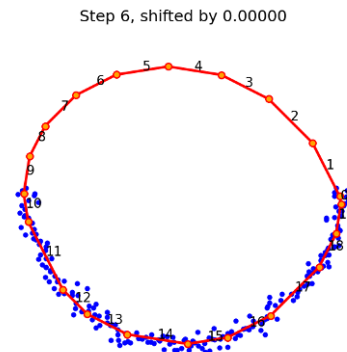
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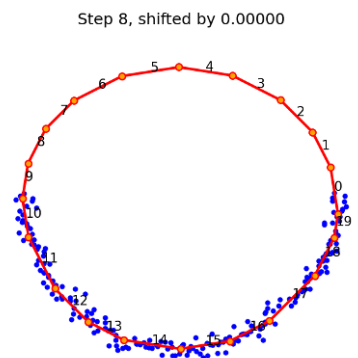
(a) Initial state



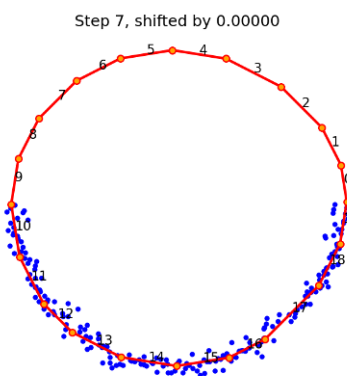
(b) $\alpha = 0.00$ (no regularization)



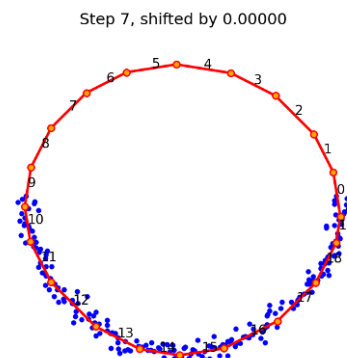
(c) $\alpha = 0.05$



(d) $\alpha = 0.20$



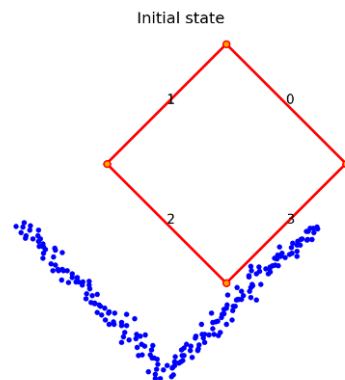
(e) $\alpha = 0.50$



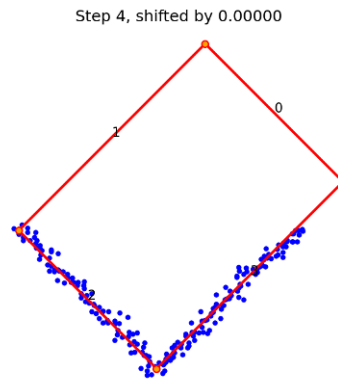
(f) $\alpha = 1.00$

Figure 10: Matching a circle to a half-circle of points with different values of the regularization parameter α .

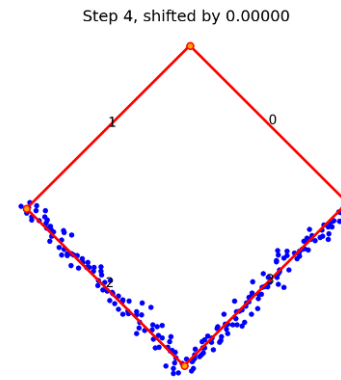
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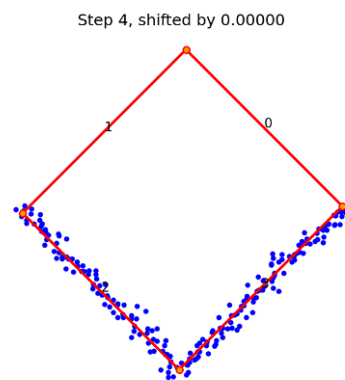
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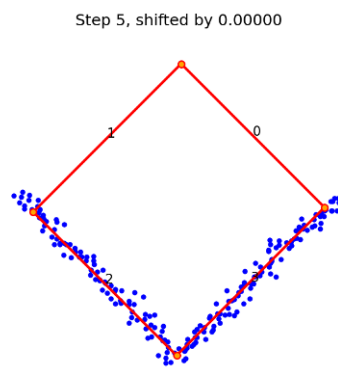
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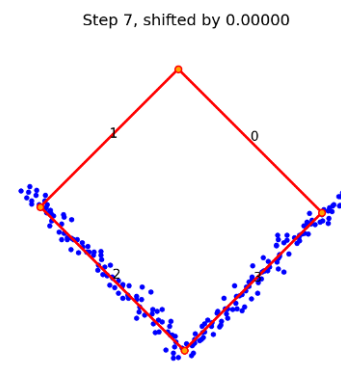
(c) $\alpha = 0.05$



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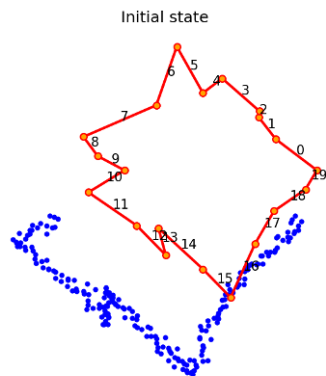
(e) $\alpha = 0.50$



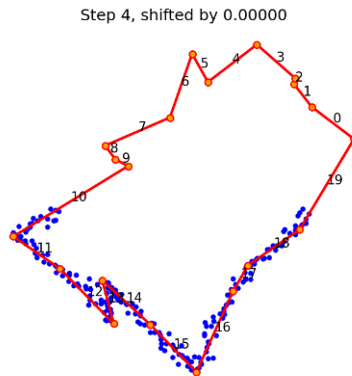
(f) $\alpha = 1.00$

Figure 11: Matching a square to points along two sides of a larger square with different values of the regularization parameter α .

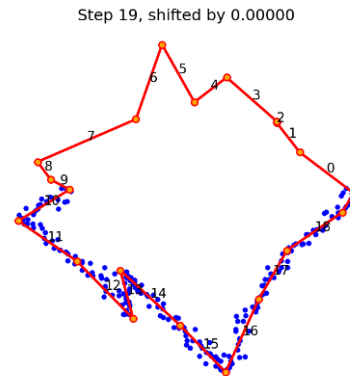
Illustrations of matching the edges to the points



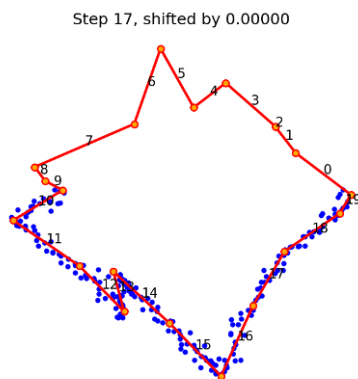
(a) Initial state



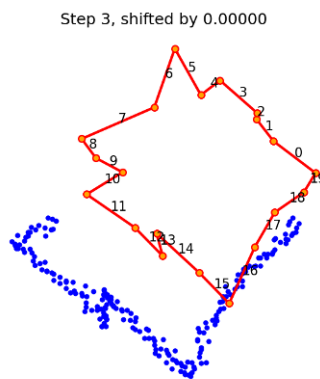
(b) $\alpha = 0.00$ (no regularization)



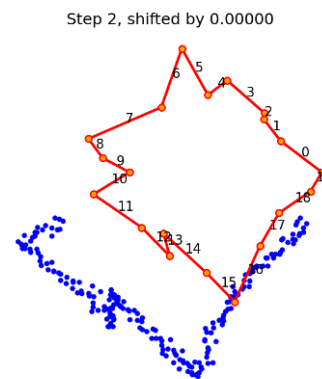
(c) $\alpha = 0.05$



(d) $\alpha = 0.20$



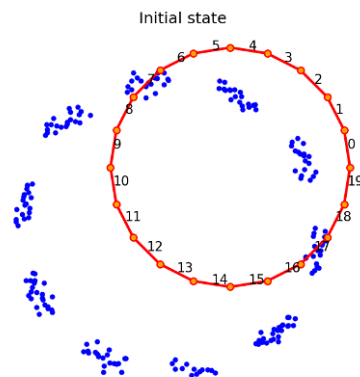
(e) $\alpha = 0.50$



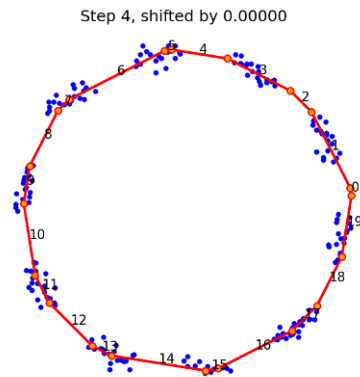
(f) $\alpha = 1.00$

Figure 12: Matching a polygon to half of its shape with points with different values of the regularization parameter α .

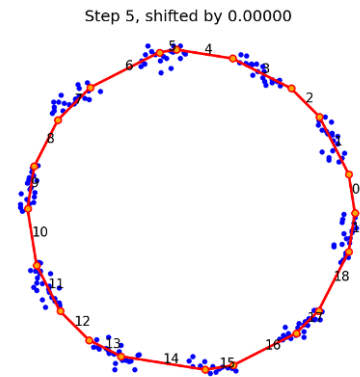
Illustrations of matching the edges to the points



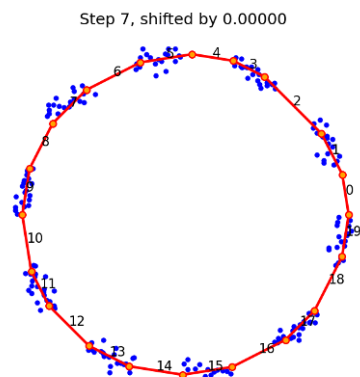
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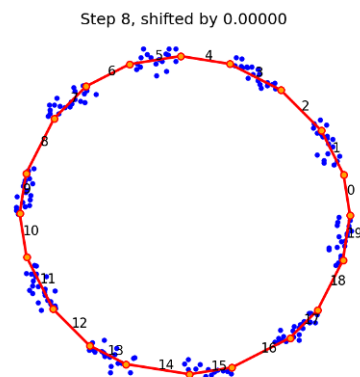
(b) $\alpha = 0.00$ (no regularization)



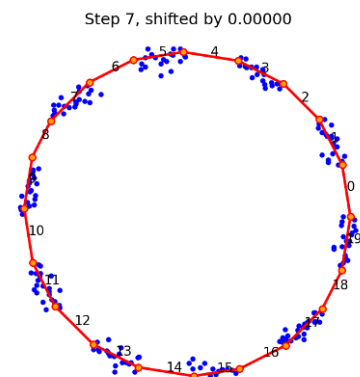
(c) $\alpha = 0.05$



(d) $\alpha = 0.20$



(e) $\alpha = 0.50$



(f) $\alpha = 1.00$

Figure 13: Matching a circle to points along half of its boundary with different values of the regularization parameter α .

Illustration with a real building

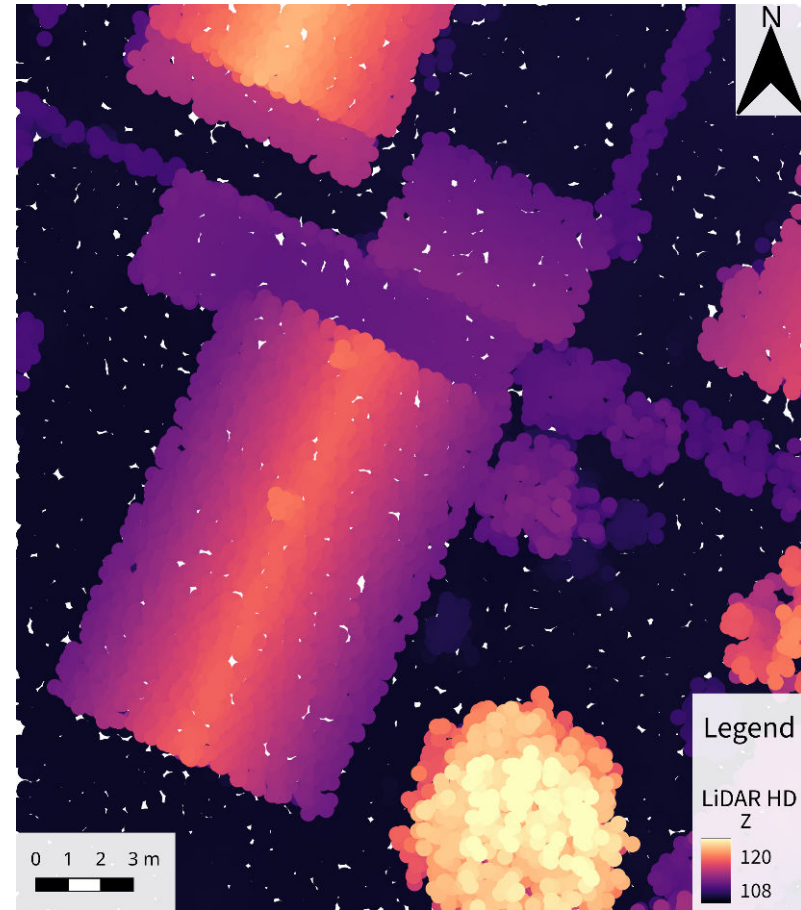
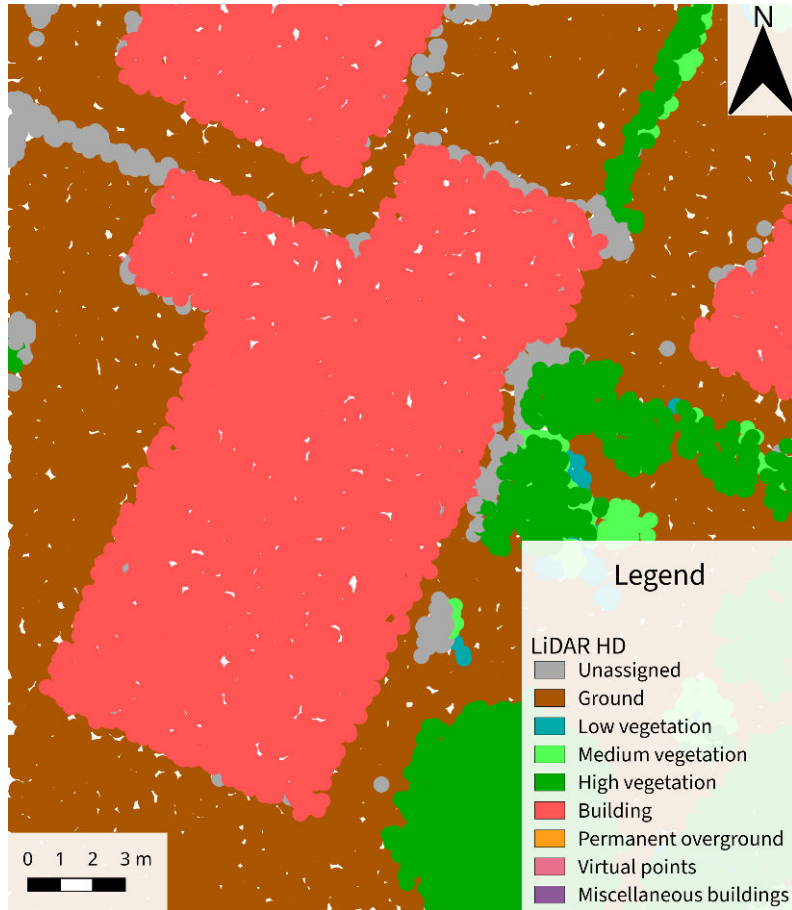


Figure 14: The LiDAR HD data.

Illustration with a real building

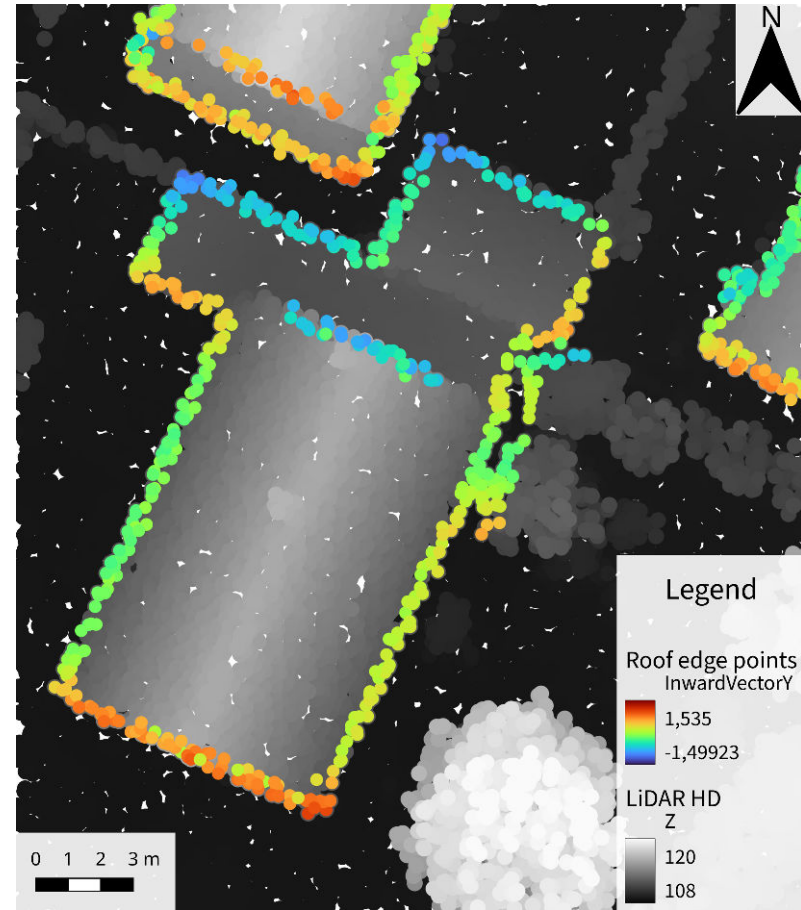
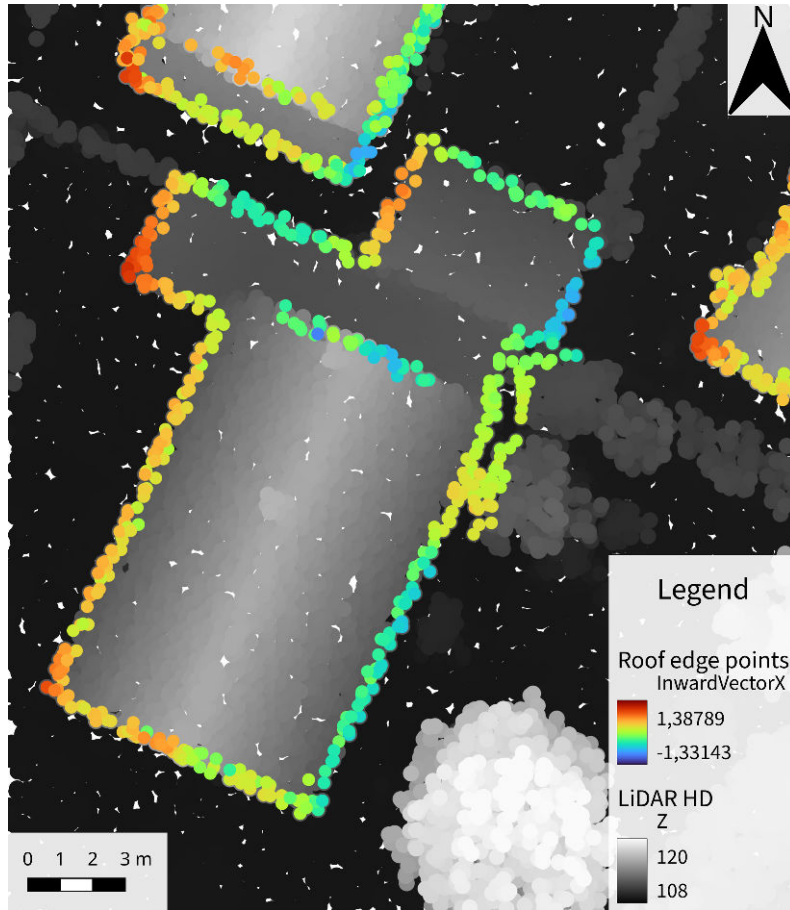


Figure 15: The detected roof edge points coloured by their inward vector.

Illustration with a real building

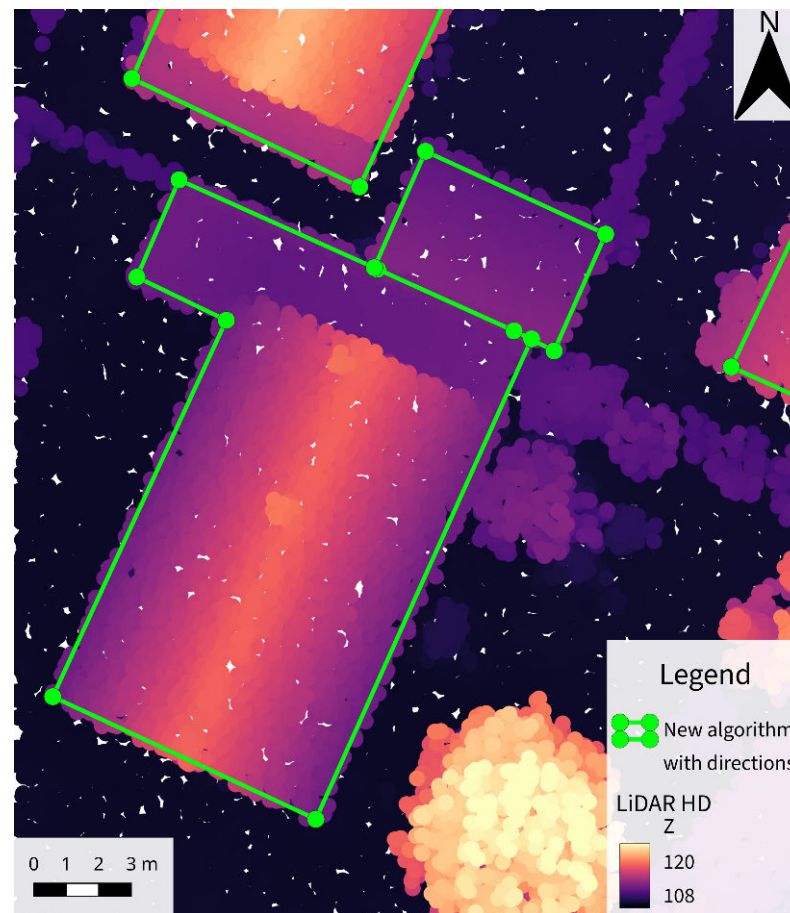
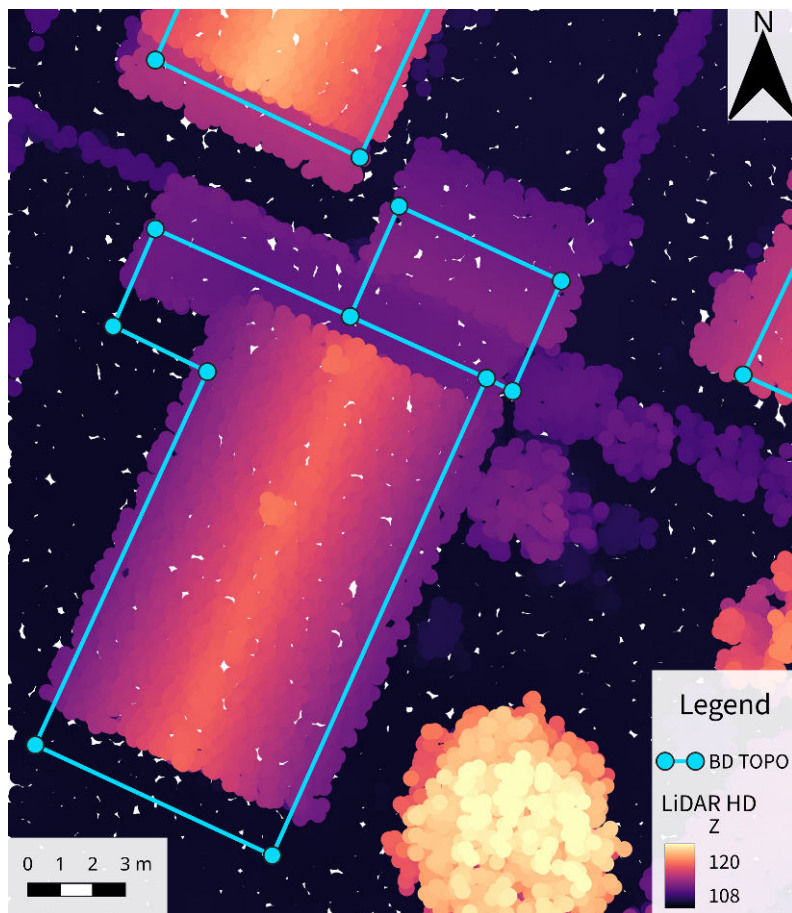


Figure 16: Comparison of BD TOPO outlines and roofprints computed with my method.

Footprint points

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Roof edge points	4
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Footprint points

1. Move the 2D roofprints to 3D creating a **3D roof outline**
2. Look for points **under** the 3D roof outline and **towards the inside** of the building

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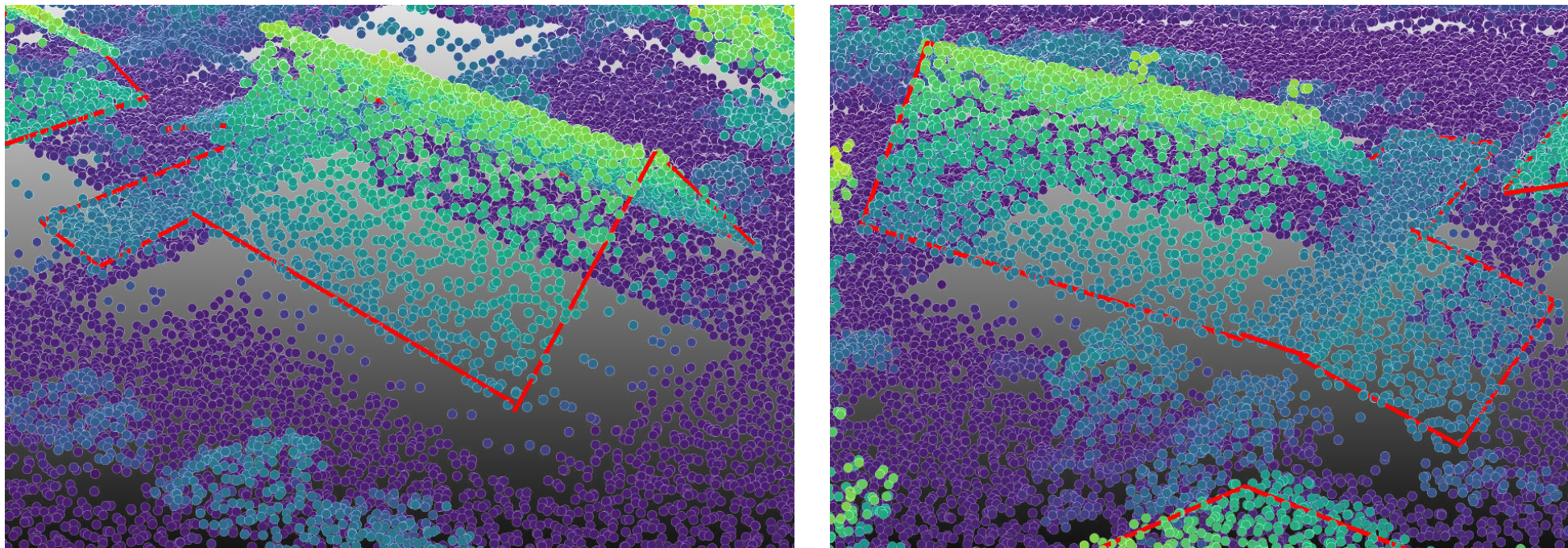


Figure 23: Illustration of the 3D roof outline.

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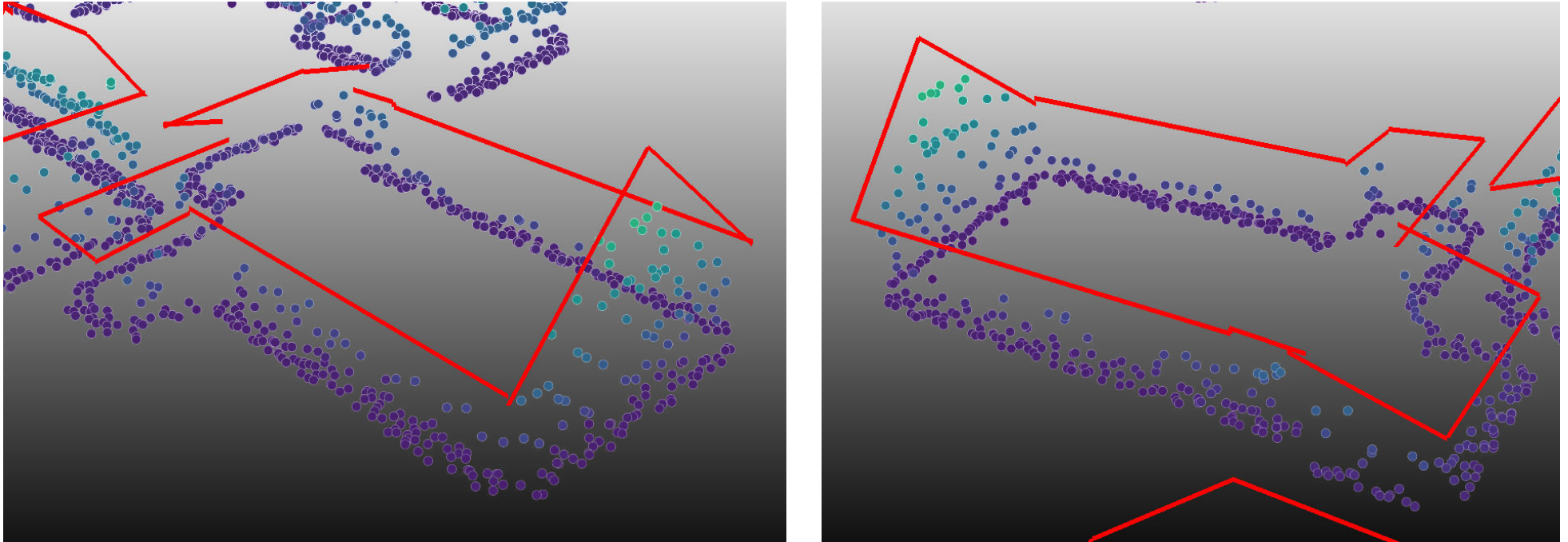


Figure 23: Illustration of the footprint points.

Creation of the footprints

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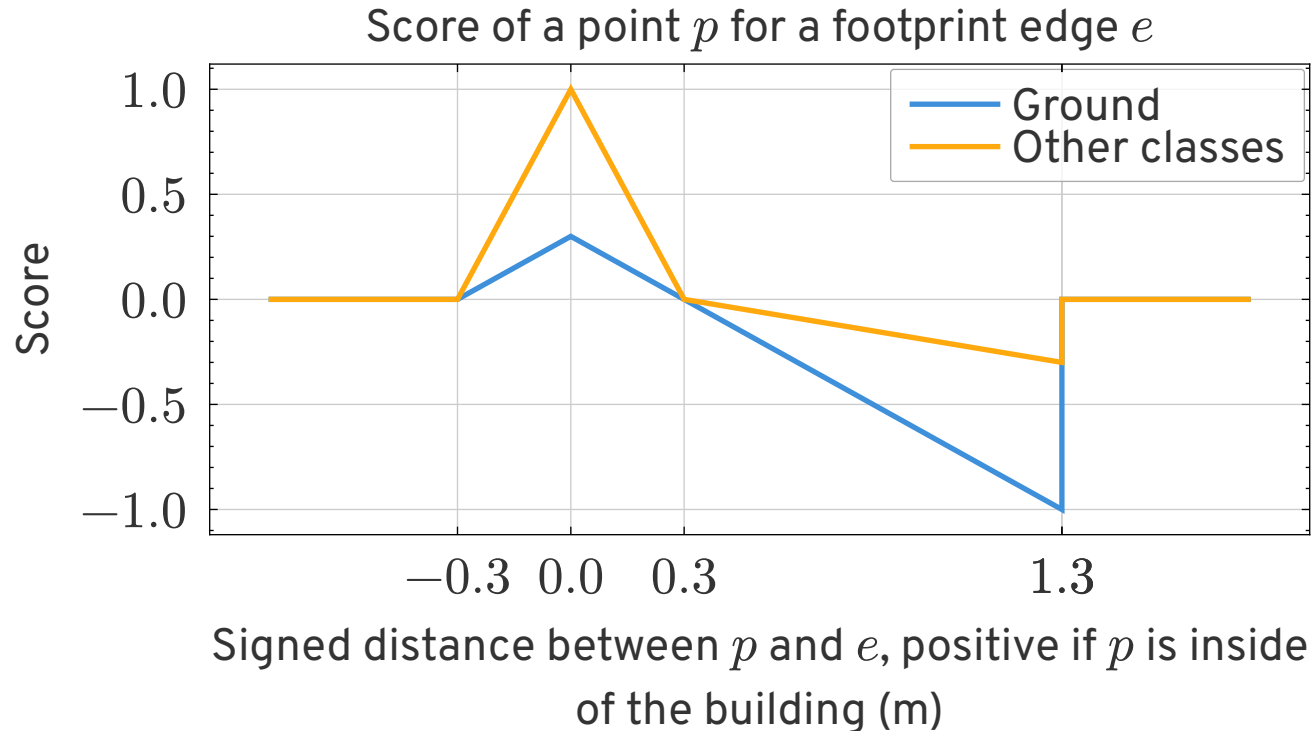
- **Sweep each roof edge towards the inside up to 1.5 metres and select the best scoring position**

Creation of the footprints

- **Sweep each roof edge towards the inside** up to 1.5 metres and select the best scoring position
- The score has two components:
 1. A **proximity term** that counts the number of points close to the edge
 2. A **penalty term** that penalizes points that are behind the edge (inside the building)

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Creation of the footprints

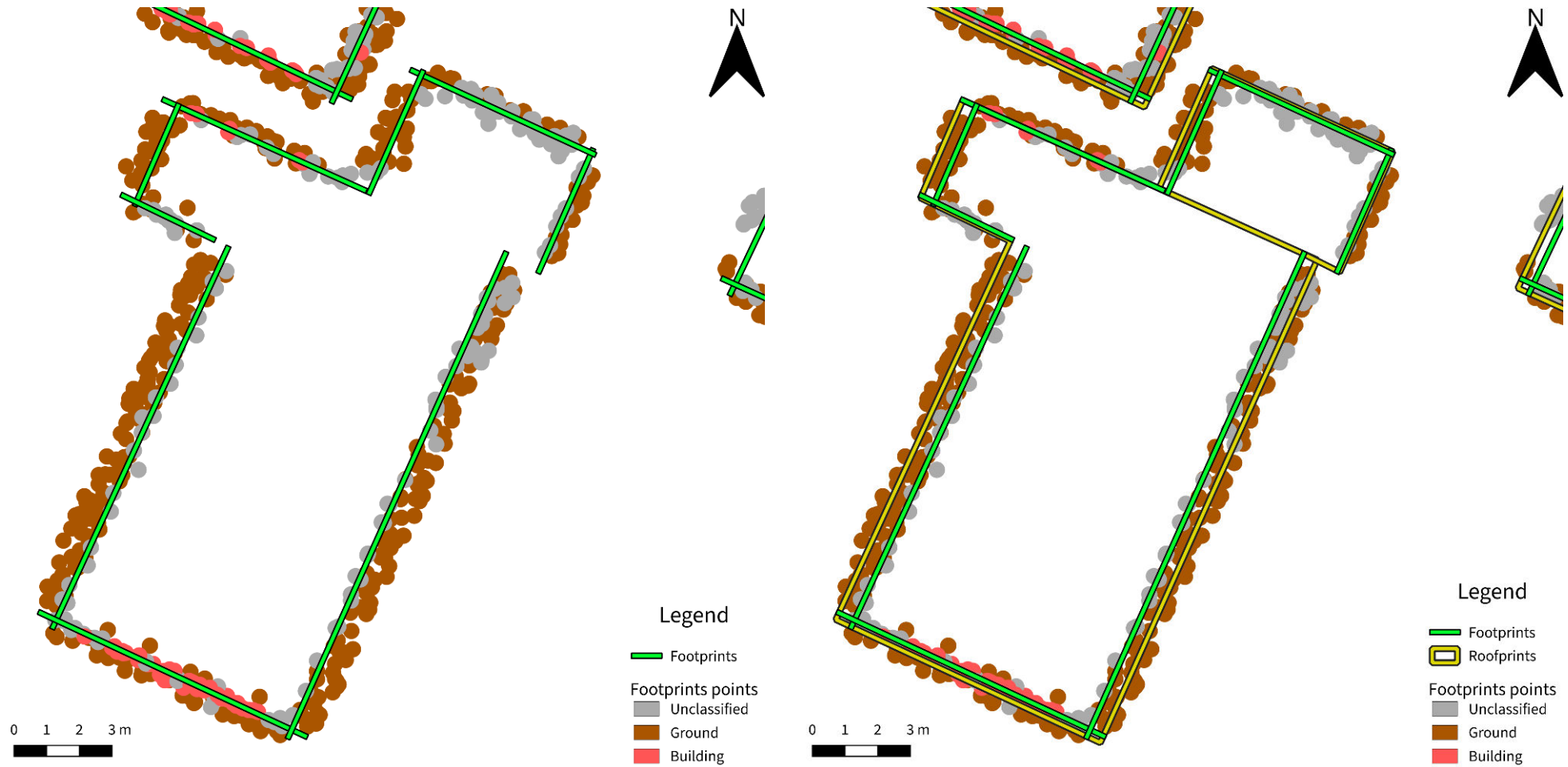


Figure 23: Illustration of the computed footprints.

Creation of the footprints

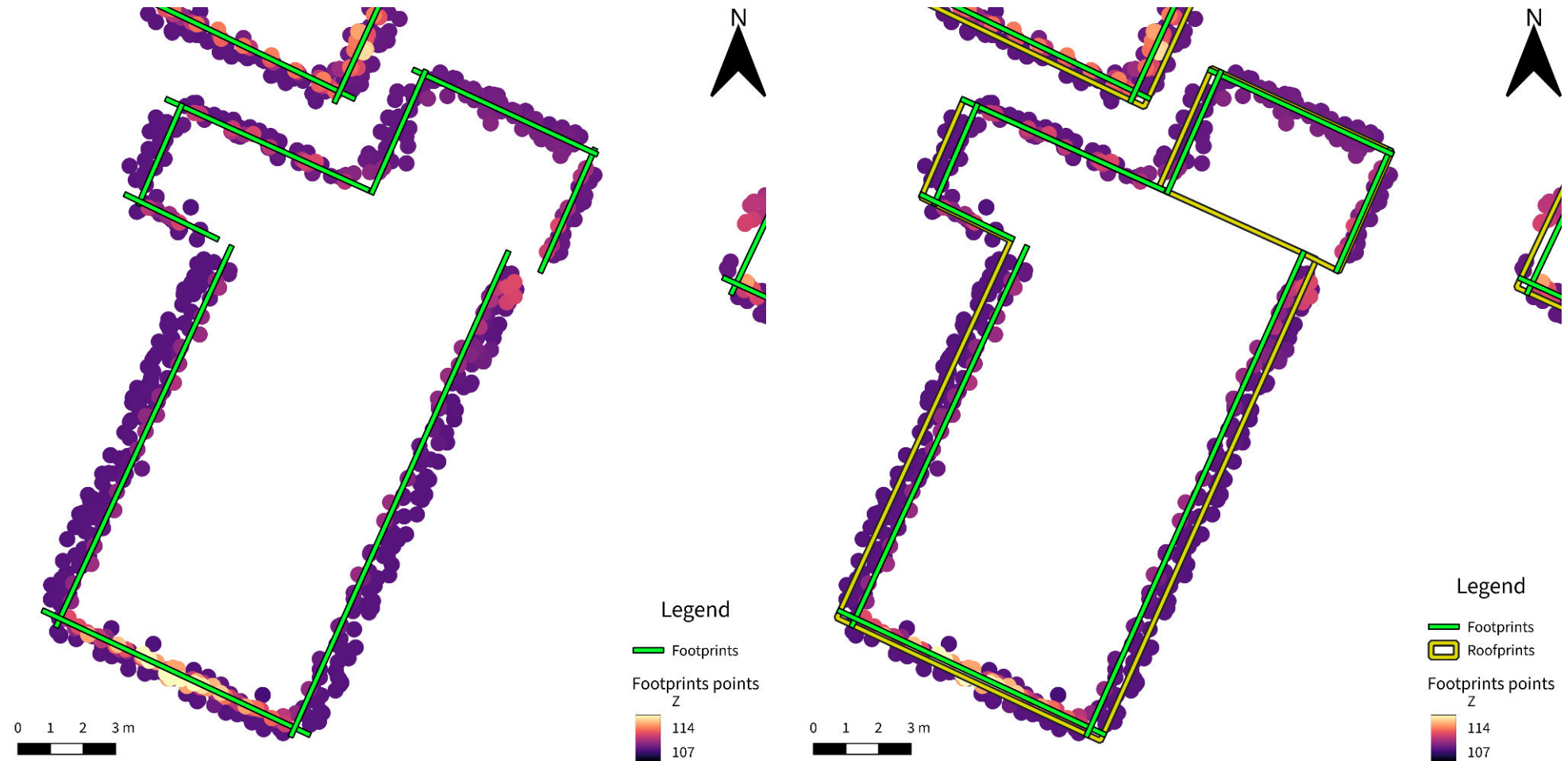


Figure 23: Illustration of the computed footprints.

Thank you for your attention!



Any questions?

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References

Biljecki, F., Ledoux, H., & Stoter, J. (2016). An improved LOD specification for 3D building models. *Computers, Environment and Urban Systems*, 59, 25–37. <https://doi.org/10.1016/j.compenvurbsys.2016.04.005>

Appendix

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Total energy to minimize

The energy that we try to minimize for each group of roofprints is the following:

$$E = \underbrace{- \sum_{i \in \mathcal{P}} w_i \max_{j \in \mathcal{L}} \{\text{score}(p_i, l_j)\}}_{\text{proximity to the points}} + \alpha \underbrace{\sum_{j \in \mathcal{L}} (|l_j| - |l_j^0|)^2}_{\text{similarity to the initial edges}}$$

Where:

- $\mathcal{P}$ is the set of points, and $\mathcal{L}$ is the set of edges (lines). $\mathcal{L}$ contains all the edges moved in any configuration and their neighbours.
- w_i is the weight of point p_i , which is independent of the lines.
- $\text{score}(p_i, l_j)$ is the score of point p_i for edge l_j , which is defined in the next slide.
- $|l_j|$ is the length of edge l_j in the current configuration, and $|l_j^0|$ is its initial length.
- α is a parameter to adjust between the two terms.

Definition of the proximity score

The score of a point p_i for an edge l_j is defined as follows:

- The score is 0 if any of the following conditions is true:
 - The orthogonal projection $p_{i\perp j}$ of p_i on the line supporting of l_j is outside of the segment l_j .
 - The distance from p_i to $p_{i\perp j}$ is greater than a certain threshold ε .
 - The dot product of the inward vector v_i of p_i with the normal n_j of l_j oriented towards the inside of the building is negative.
- Otherwise, the score is:

$$\text{score}(p_i, l_j) = \underbrace{(v_i \cdot n_j)}_{\substack{\text{alignment of} \\ \text{point and edge} \\ \text{'normals'}}} \times \underbrace{\left(1 - \frac{|p_i - p_{i\perp j}|}{\varepsilon}\right)}_{\text{proximity to the edge}} \geq 0$$

We use $\varepsilon = 30$ centimetres.

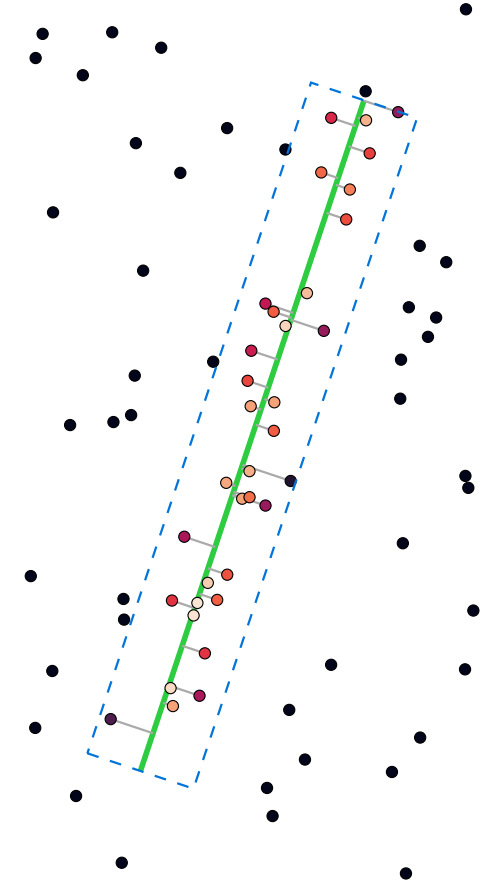


Figure 23: Illustration of the proximity score for an isolated edge.

Definition of the inward direction

The goal of the **inward direction** is to be as close as possible to the 2D normal of the roof edge, pointing towards the inside of the building. To compute it for a given point p_i , we use the following method:

1. Identify all the points p_j that are less than a certain distance δ from p_i .
2. For each point p_j , compute the vector from p_i to p_j , and normalize it into a unit vector $u_{i \rightarrow j}$.
3. Compute the inward vector v_i as the average of the vectors $u_{i \rightarrow j}$:

$$v_i = \frac{1}{|\mathcal{B}(p_i, \delta)|} \sum_{p_j \in \mathcal{B}(p_i, \delta)} \frac{p_j - p_i}{|p_j - p_i|}$$

We use $\delta = 2$ metres.