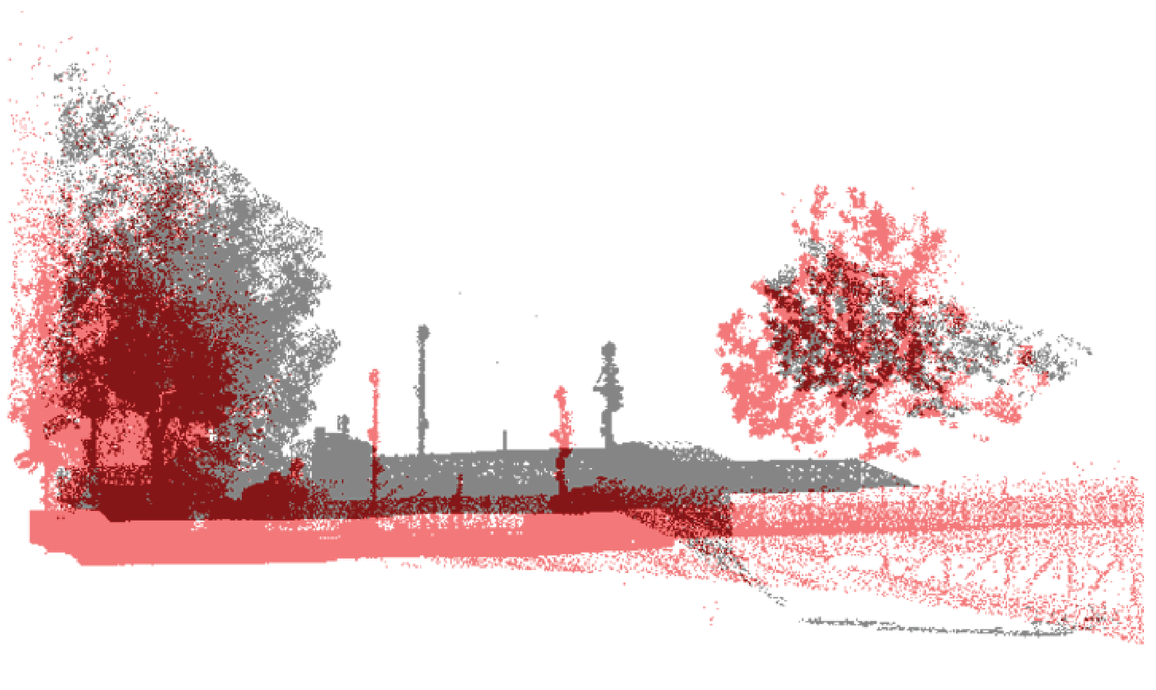
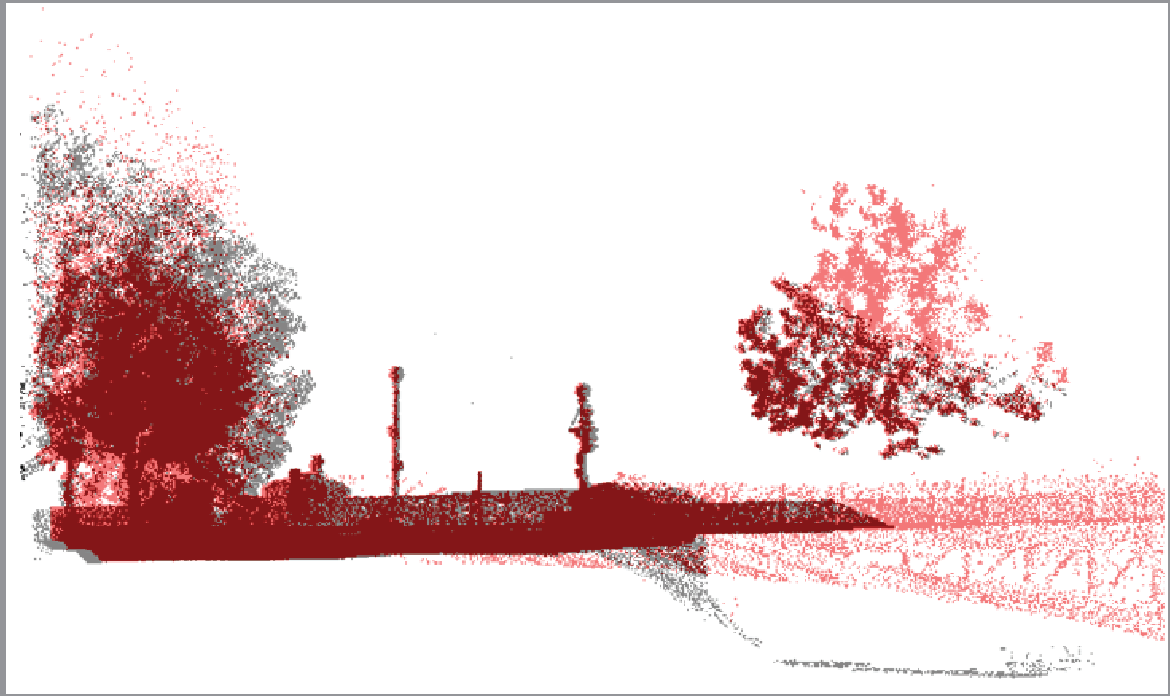
IMAGE-BASED METHOD FOR THE PAIRWISE REGISTRATION OF MOBILE LASER SCANNING POINT CLOUDS





ANTRIA CHRISTODOULOU

MSc Geomatics

October 2018

Peter van Oosterom, Ravi Peters

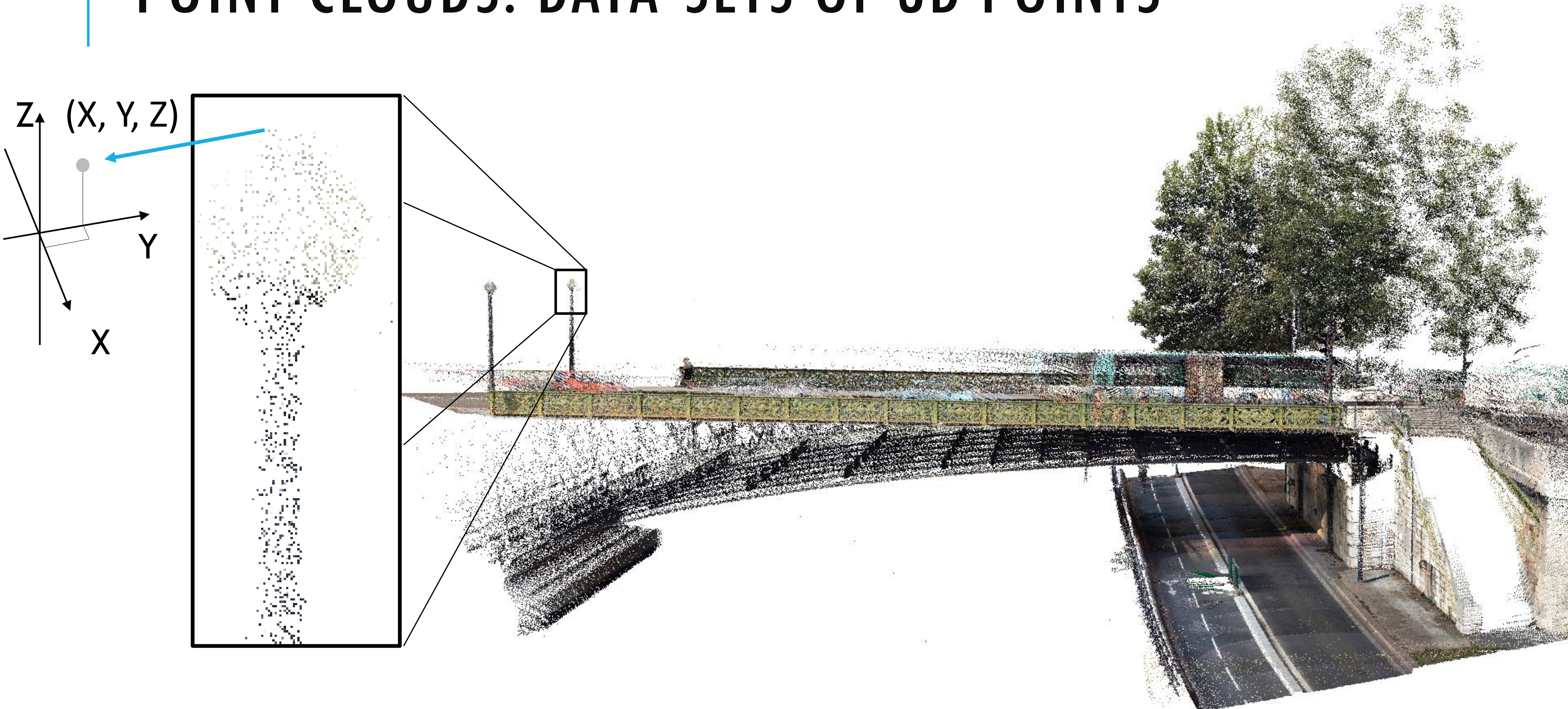
Peter Joosten, Berry van Someren

TU Delft

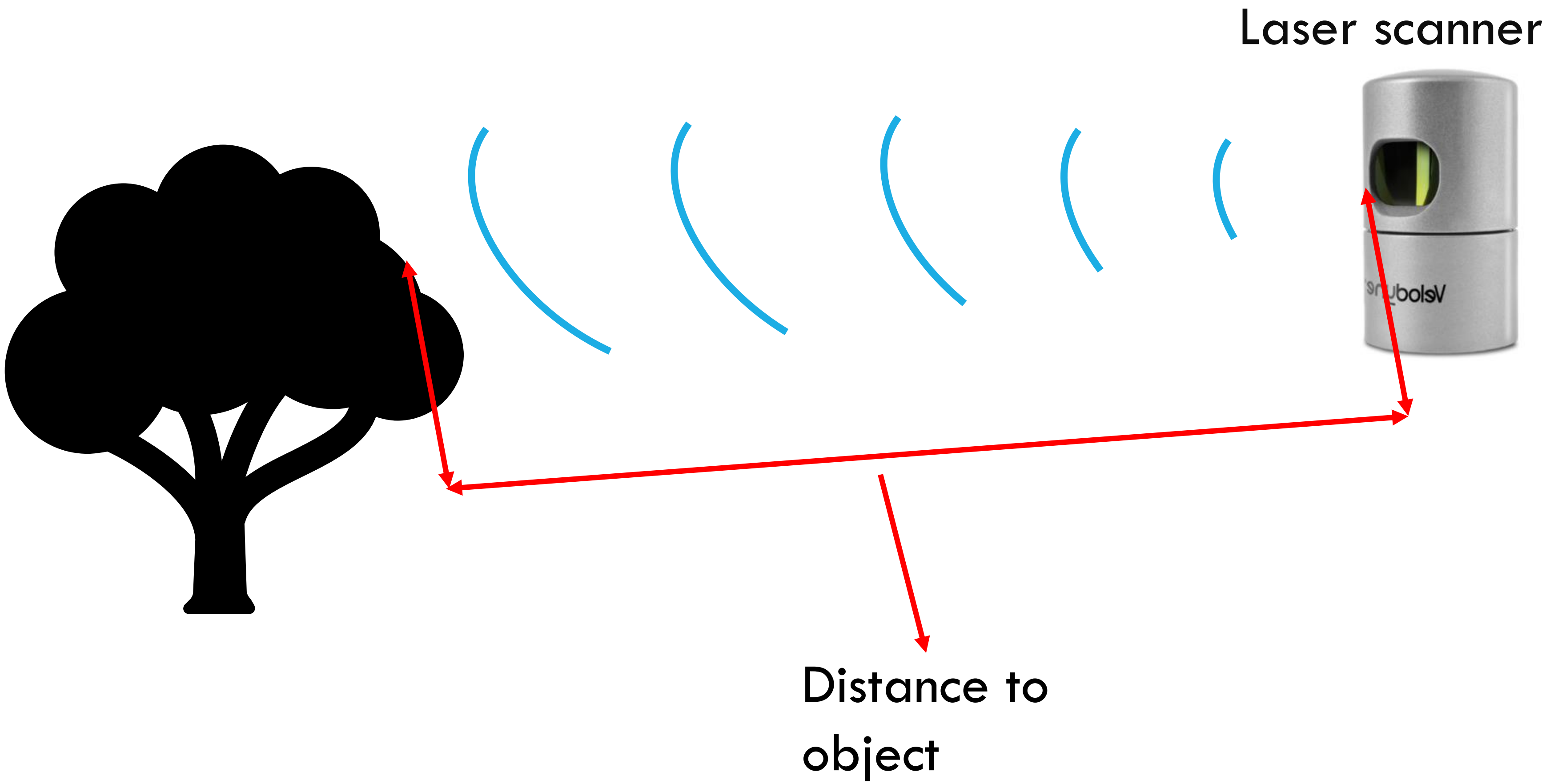
cyclomedia Smart Imagery Solutions

Paper: https://bit.ly/2NIQuUx

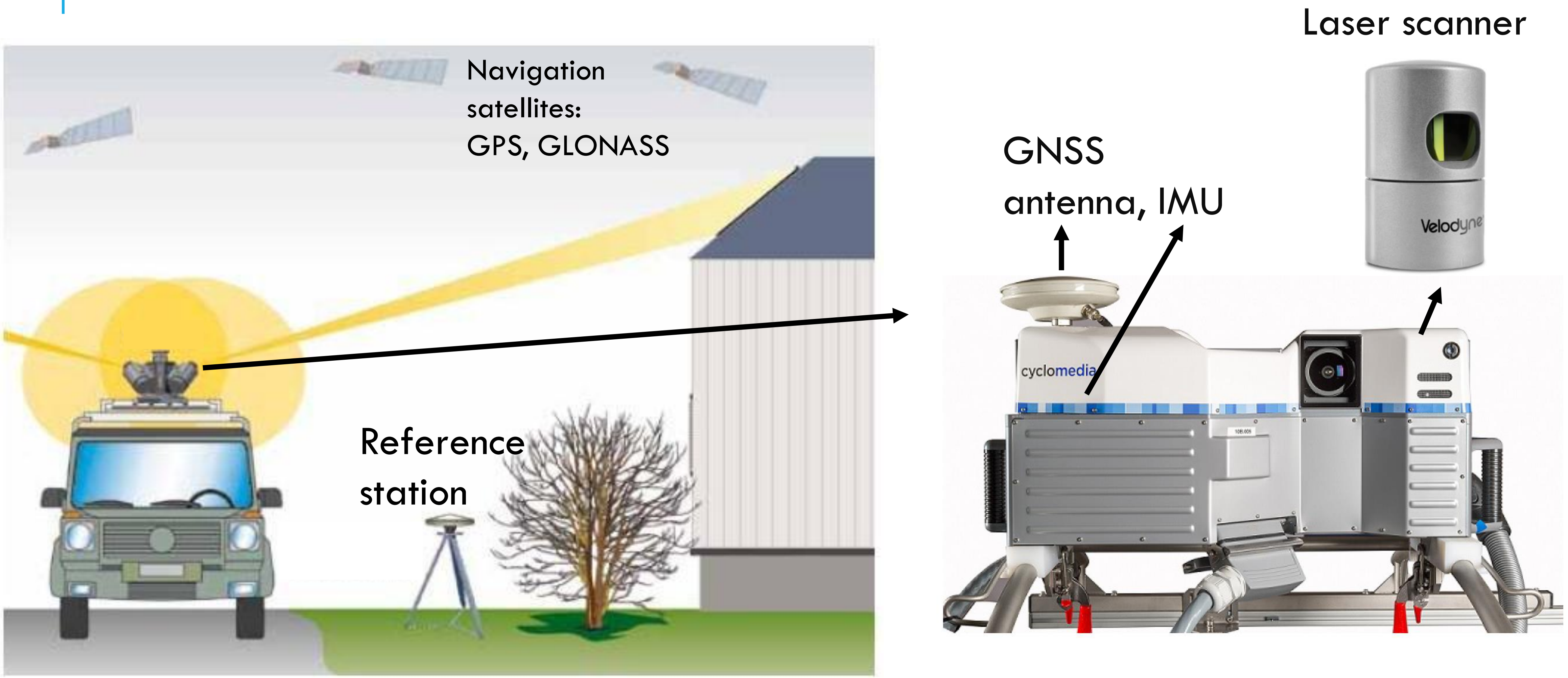
POINT CLOUDS: DATA-SETS OF 3D POINTS



LASER SCANNING

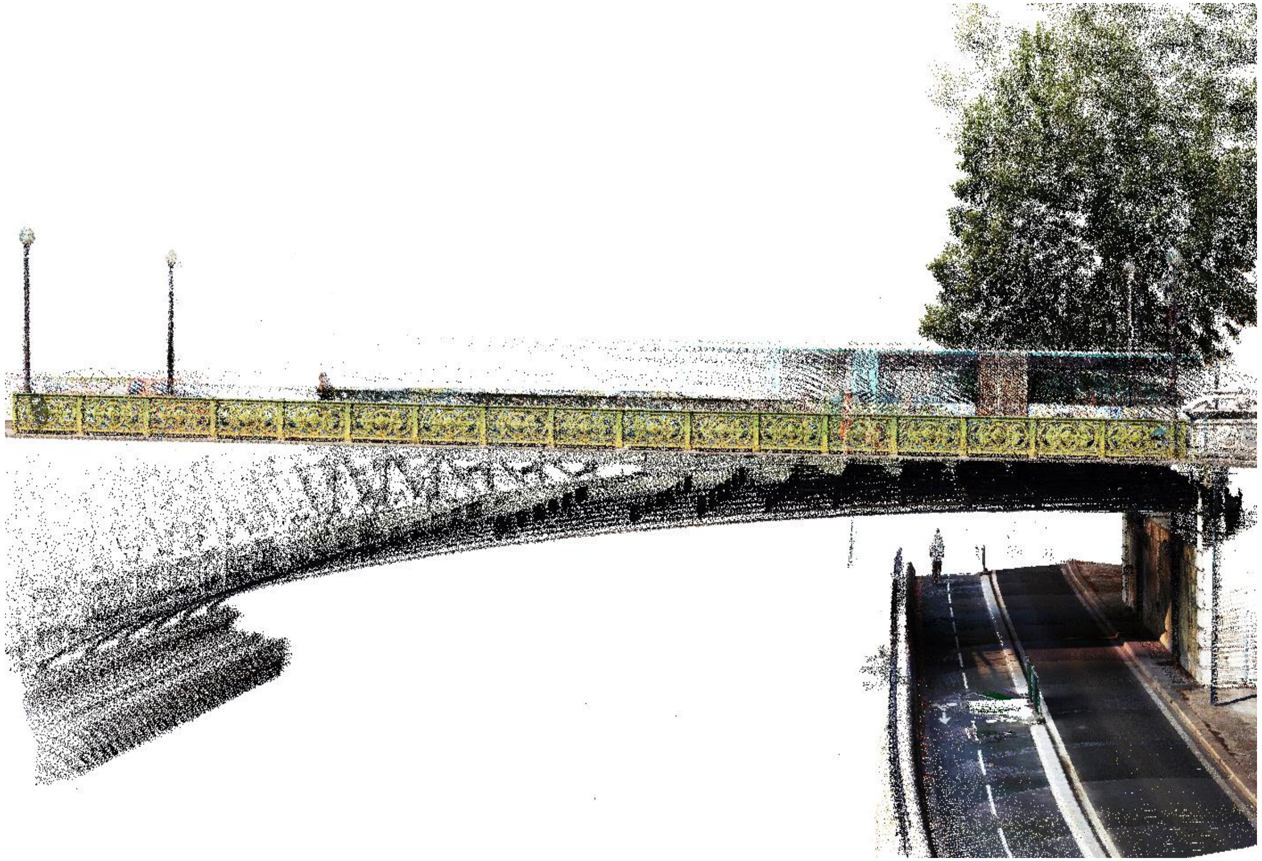


MOBILE LASER SCANNING



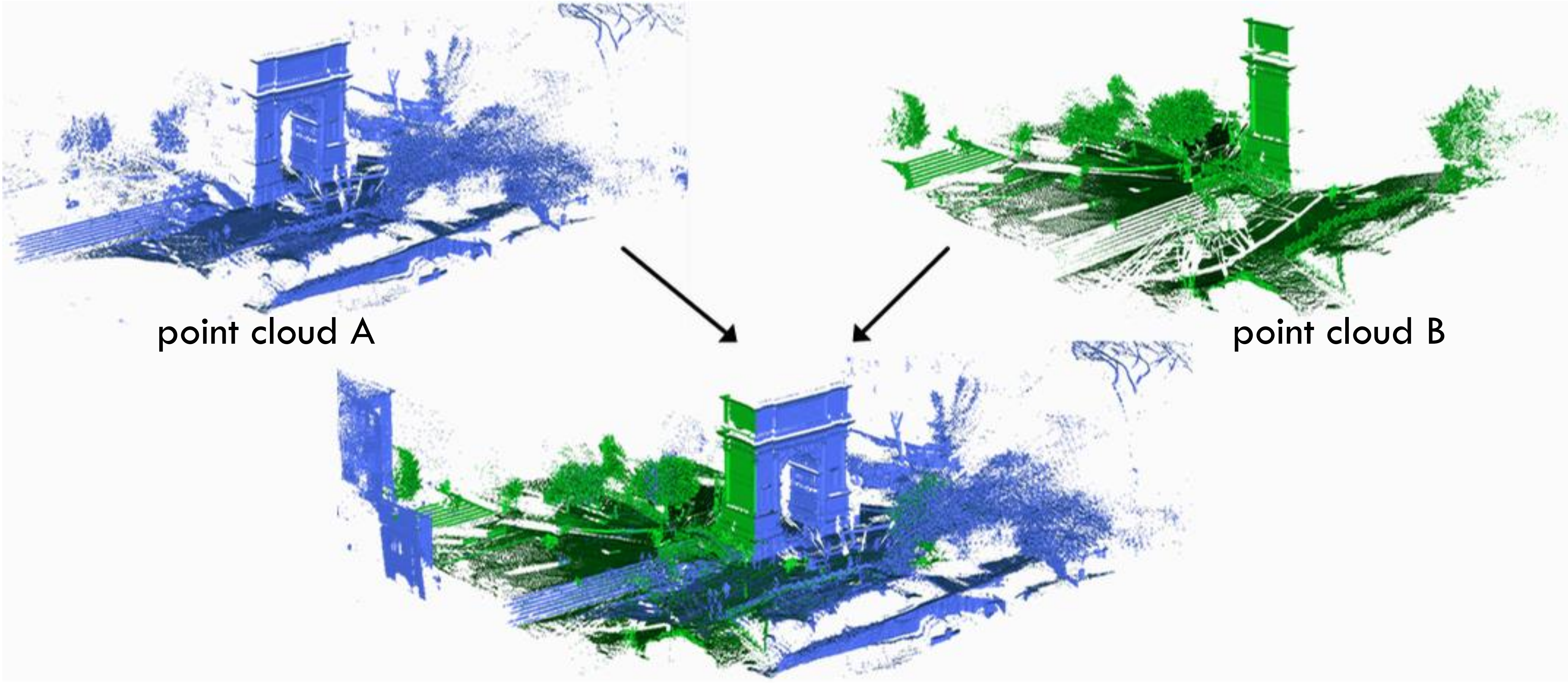
MOBILE LASER SCANNING POINT CLOUDS

Street-view image



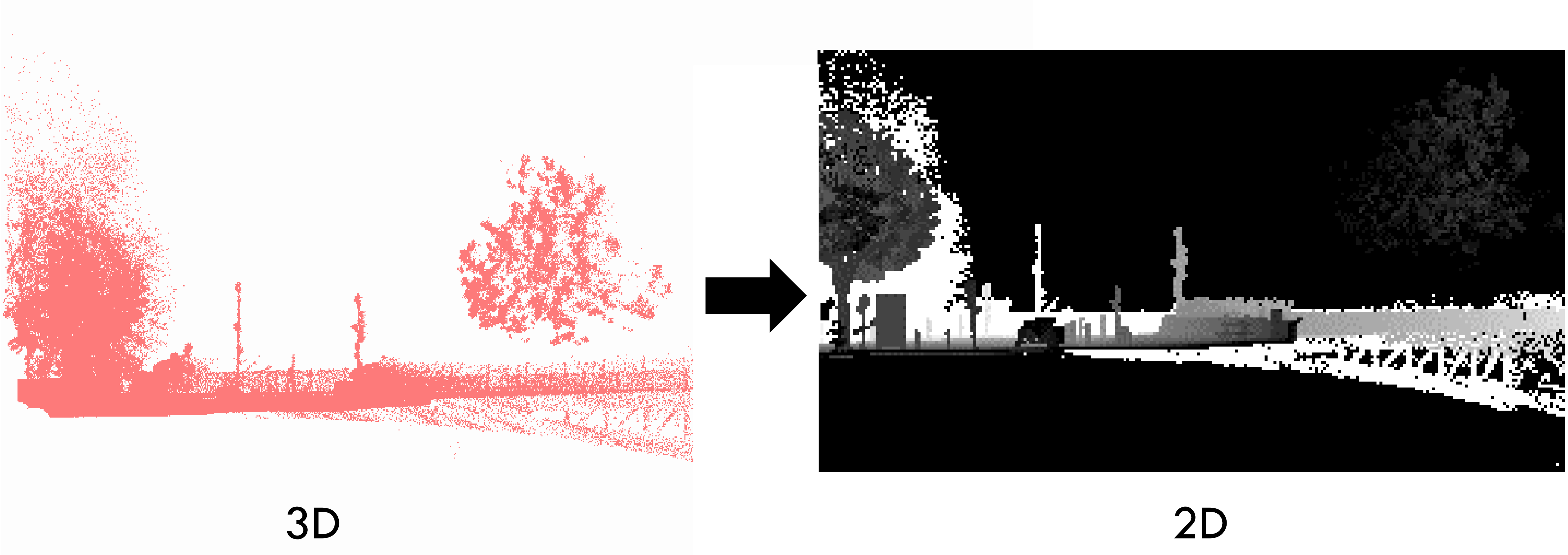
Street-view point cloud

PAIRWISE REGISTRATION

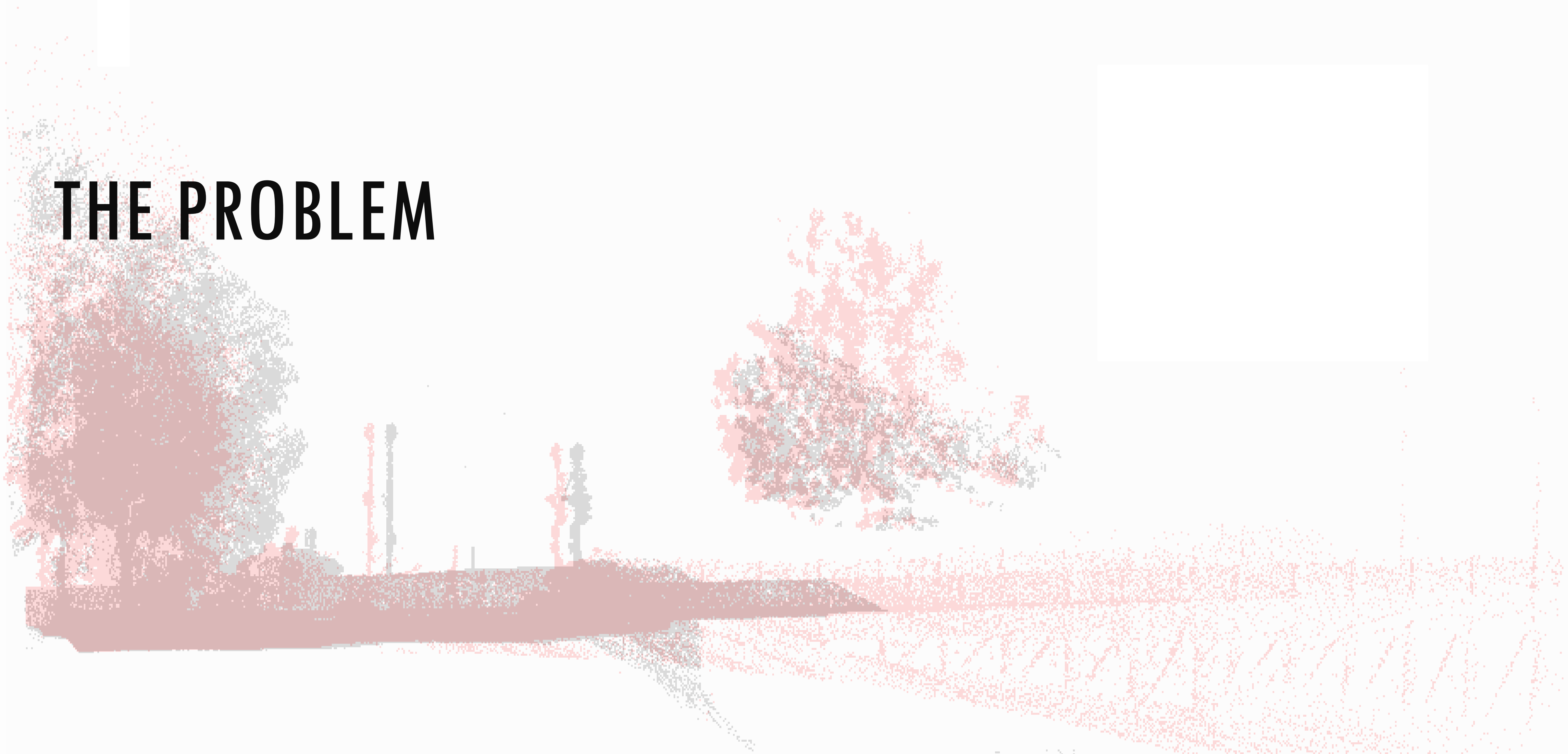


point cloud A&B registered (aligned)

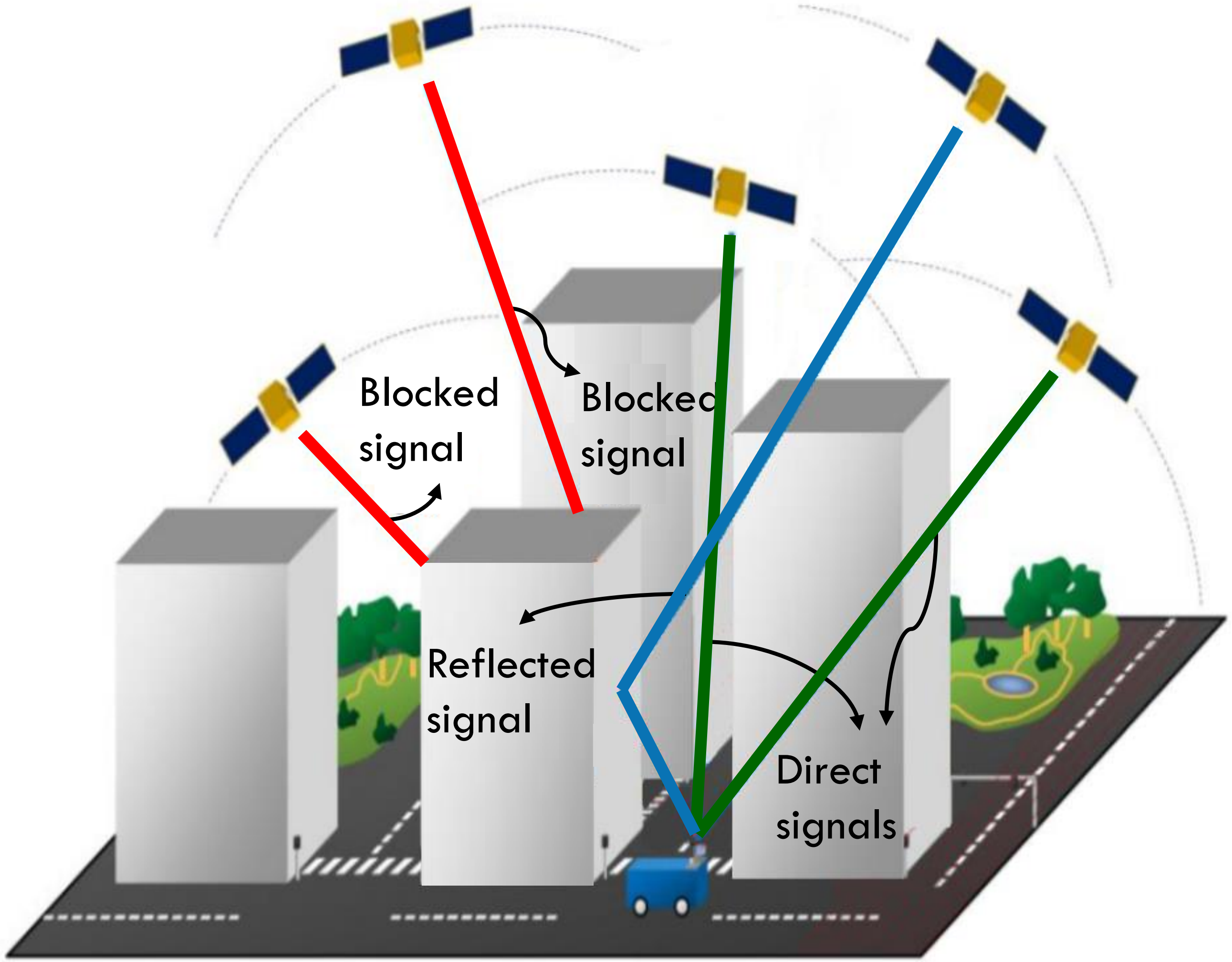
IMAGE-BASED METHOD



THE PROBLEM



THE PROBLEM



Available satellites may not be sufficient for the determination of the positioning

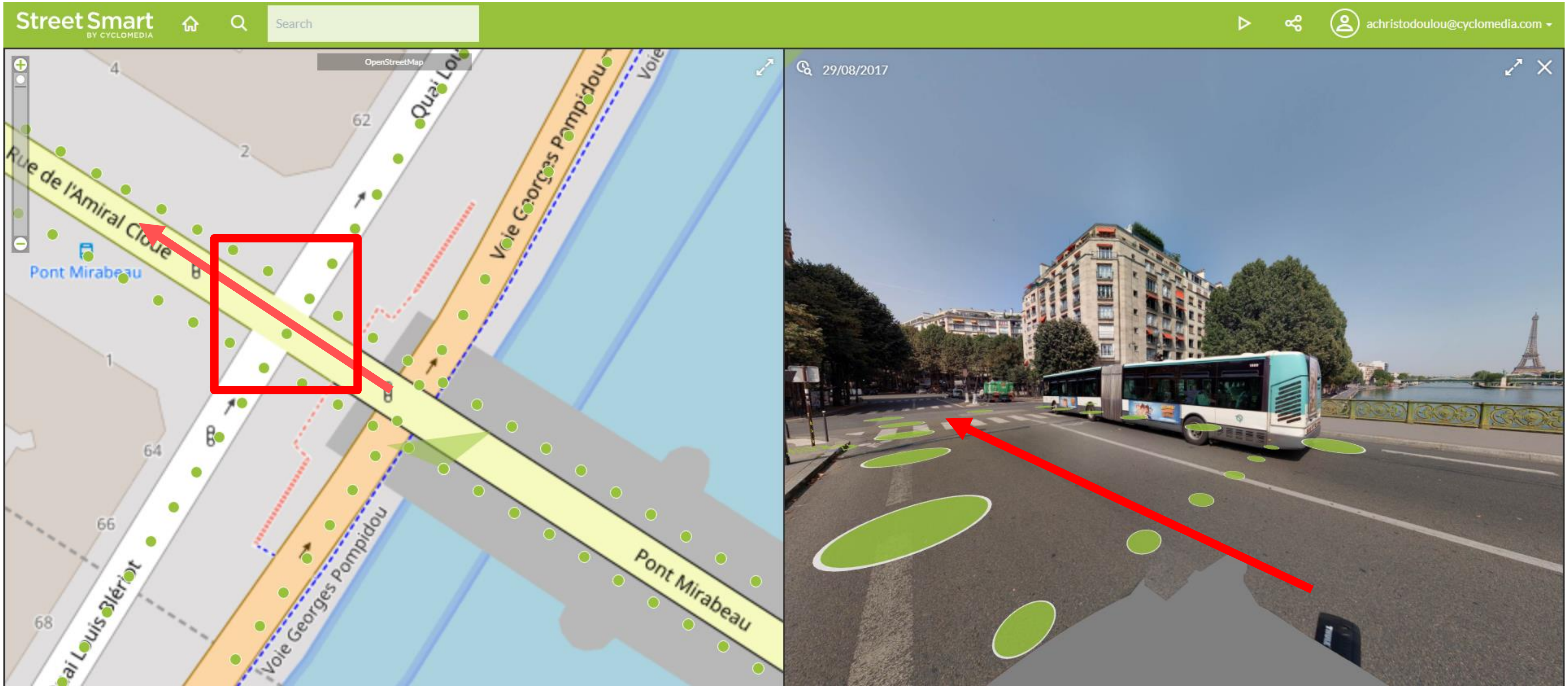
EFFECT OF THE PROBLEM

Noticeable at streets' crossings

TO ACQUIRE A COMPLETE REPRESENTATION

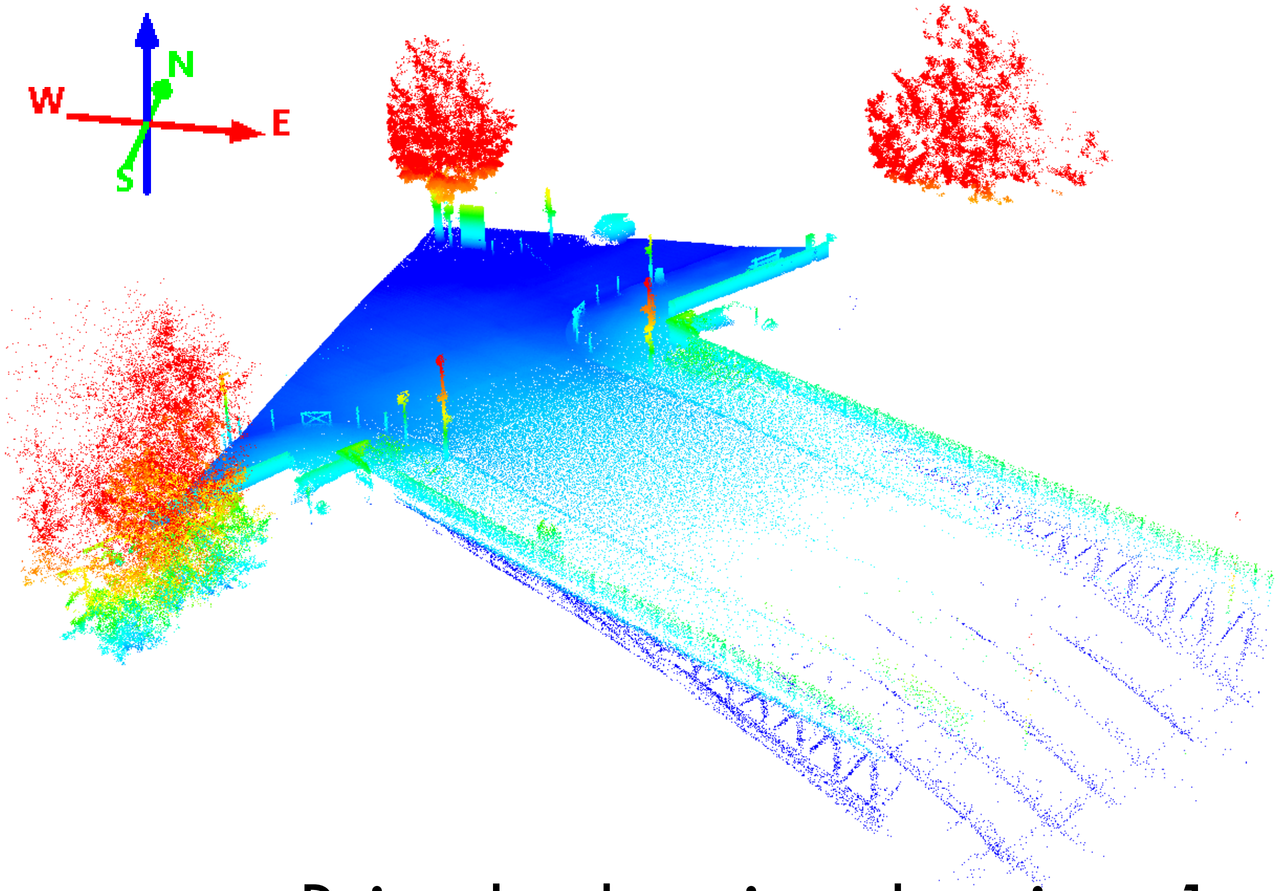
Scanning at time t1

TO ACQUIRE A COMPLETE REPRESENTATION

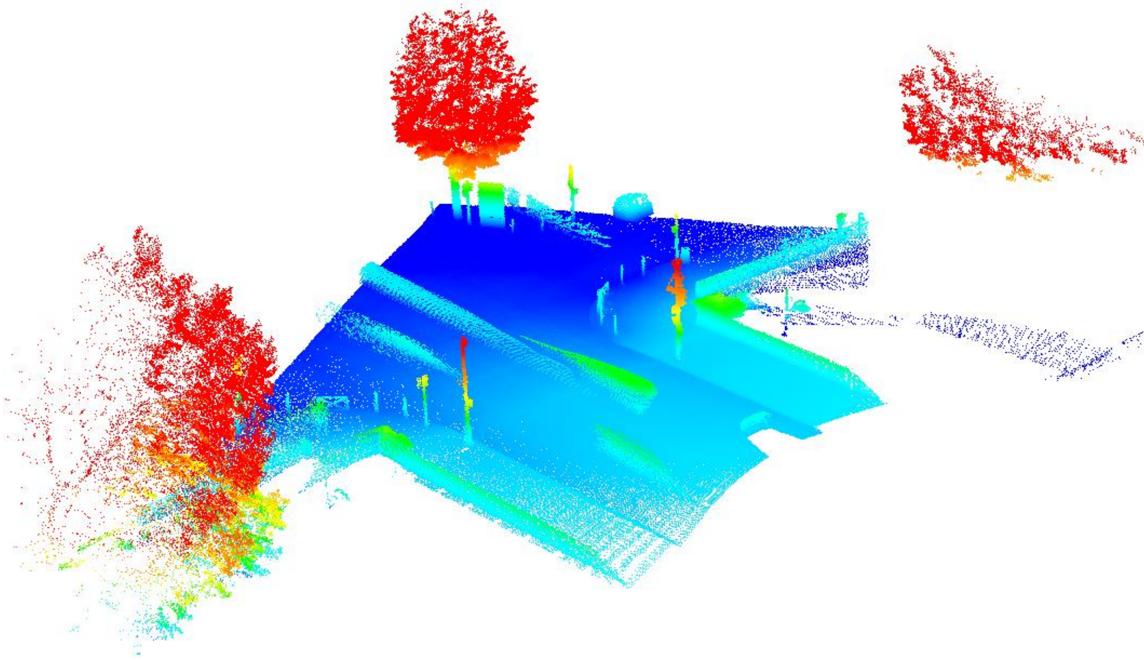


Scanning at time t2

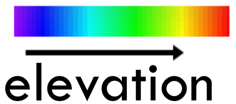
TWO OVERLAPPING POINT CLOUDS FROM THE SAME SCENE



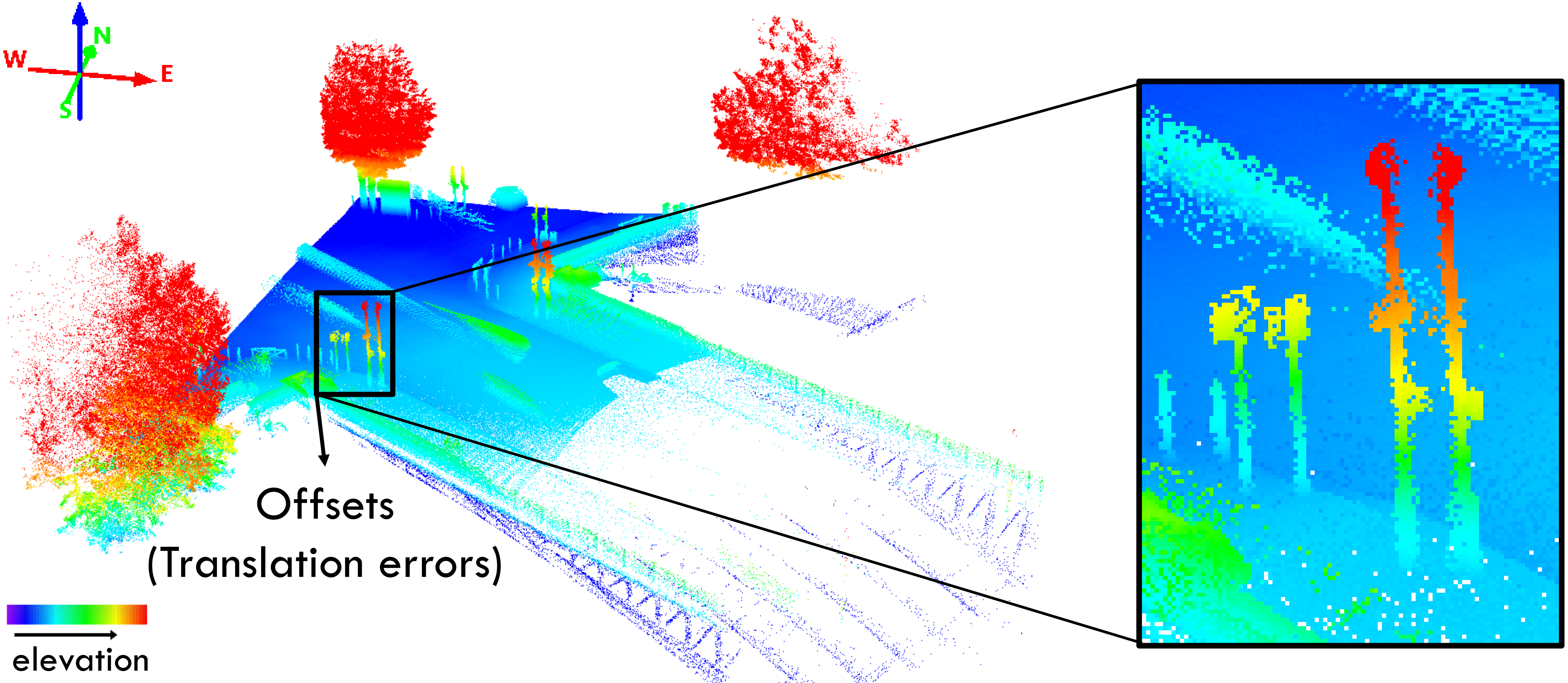
Point cloud retrieved at time t1



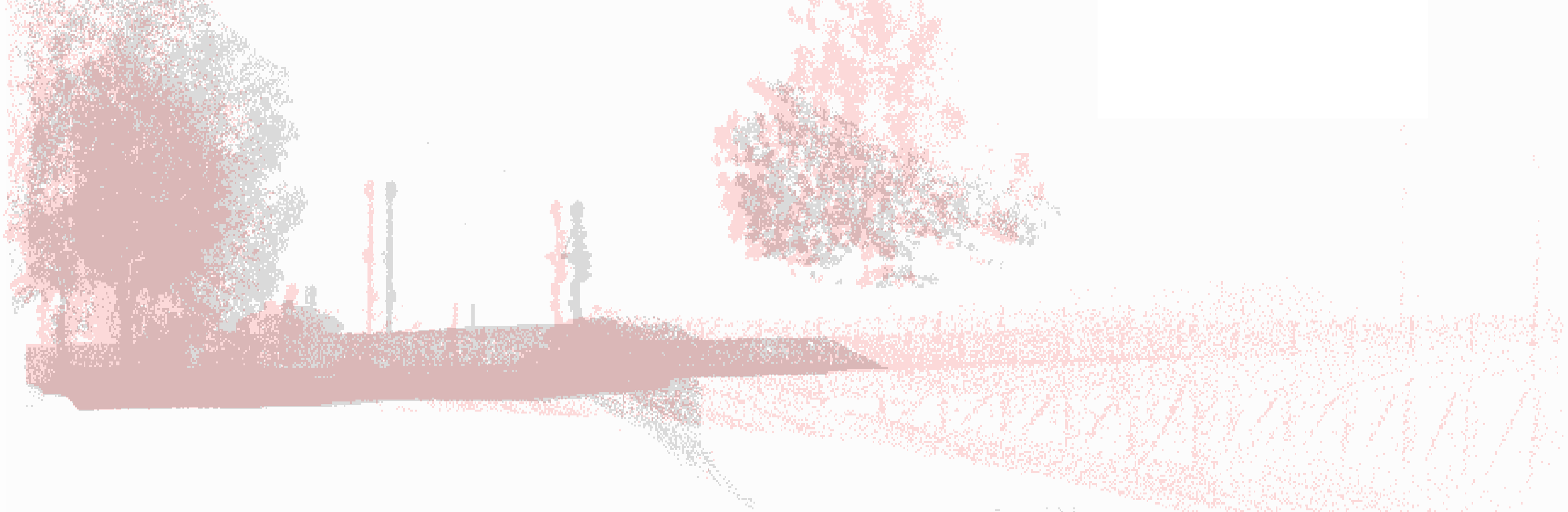
Point cloud retrieved at time t2



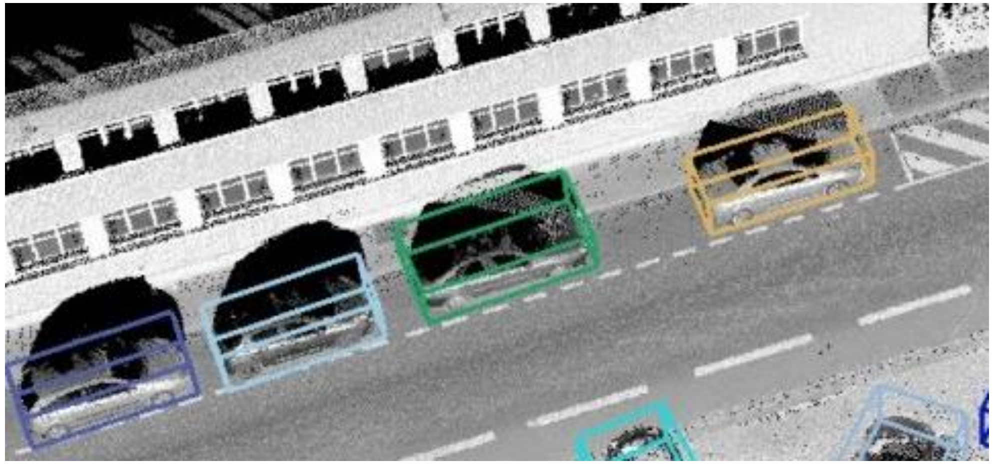
SCANNING OF THE SAME SCENE AT TIMES T1 & T2



WHY TO REGISTER POINT CLOUDS?



MOTIVATION

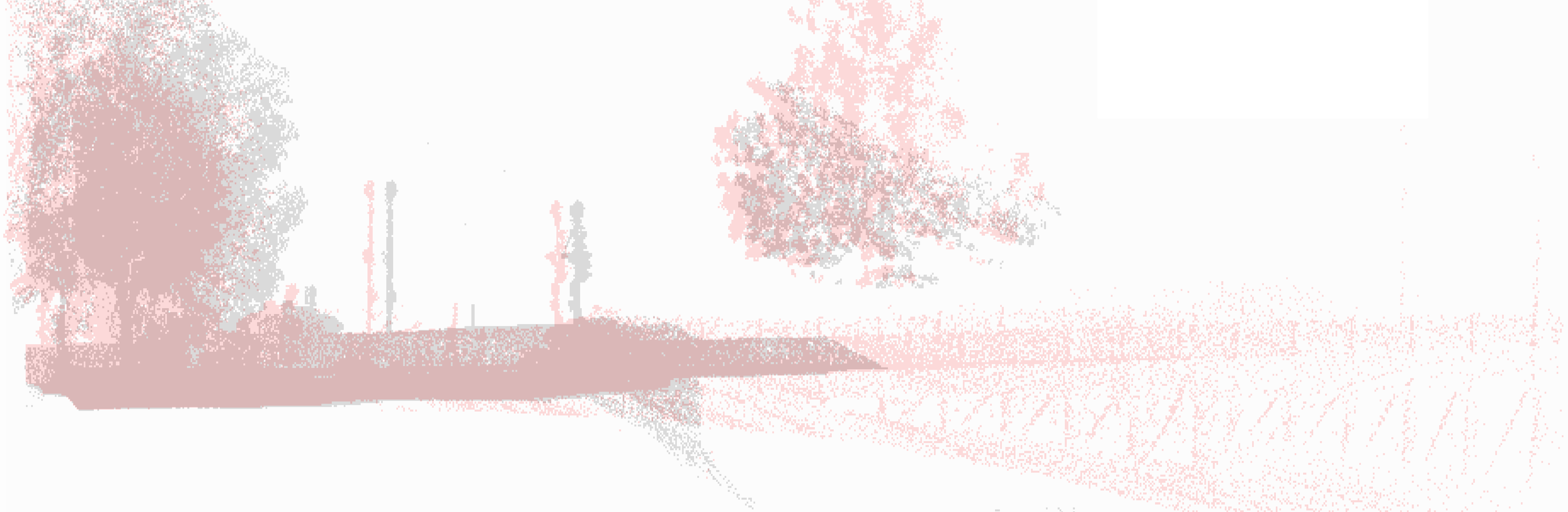


Object recognition

UAV navigation-Disaster Management

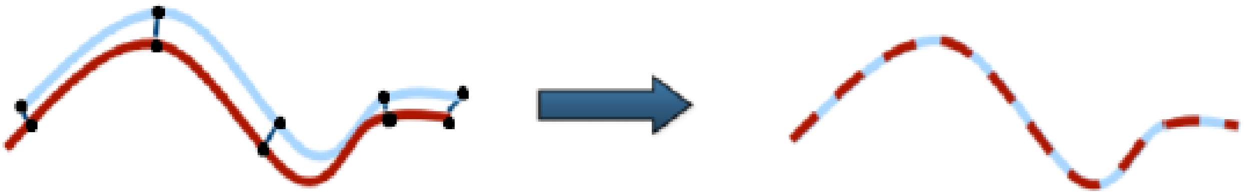
Office measurements

RELATED WORK: 3D LOCAL POINT CLOUD REGISTRATION



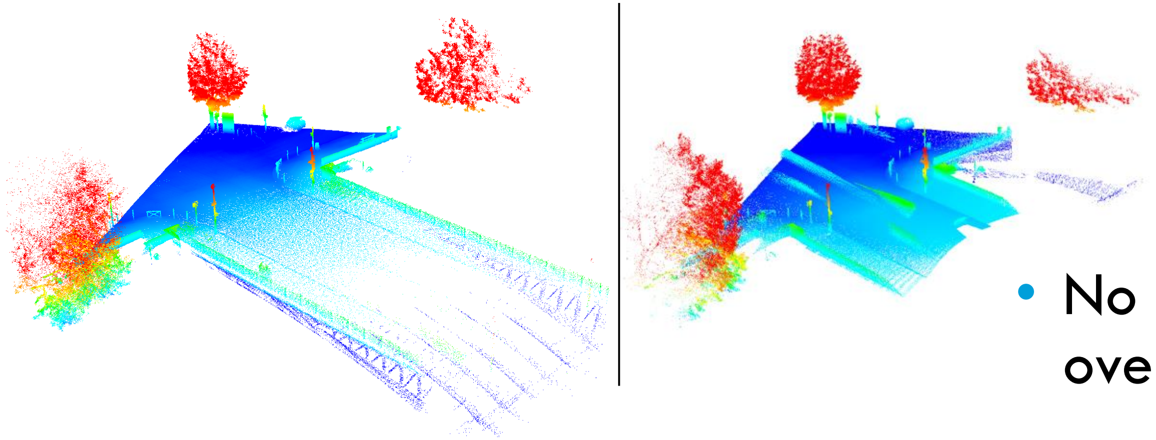
COMMONLY USED: ITERATIVE CLOSEST POINT (ICP) ALGORITHM

- In general ICP-based algorithms perform good when:

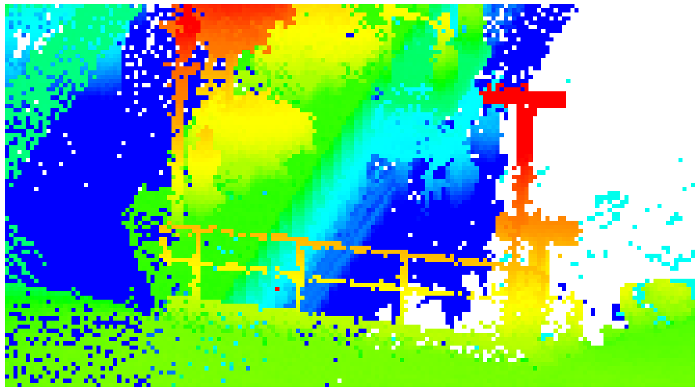


  - Big overlap
  - Initial positions have small offset

- However, in Mobile Laser Scanning point clouds:

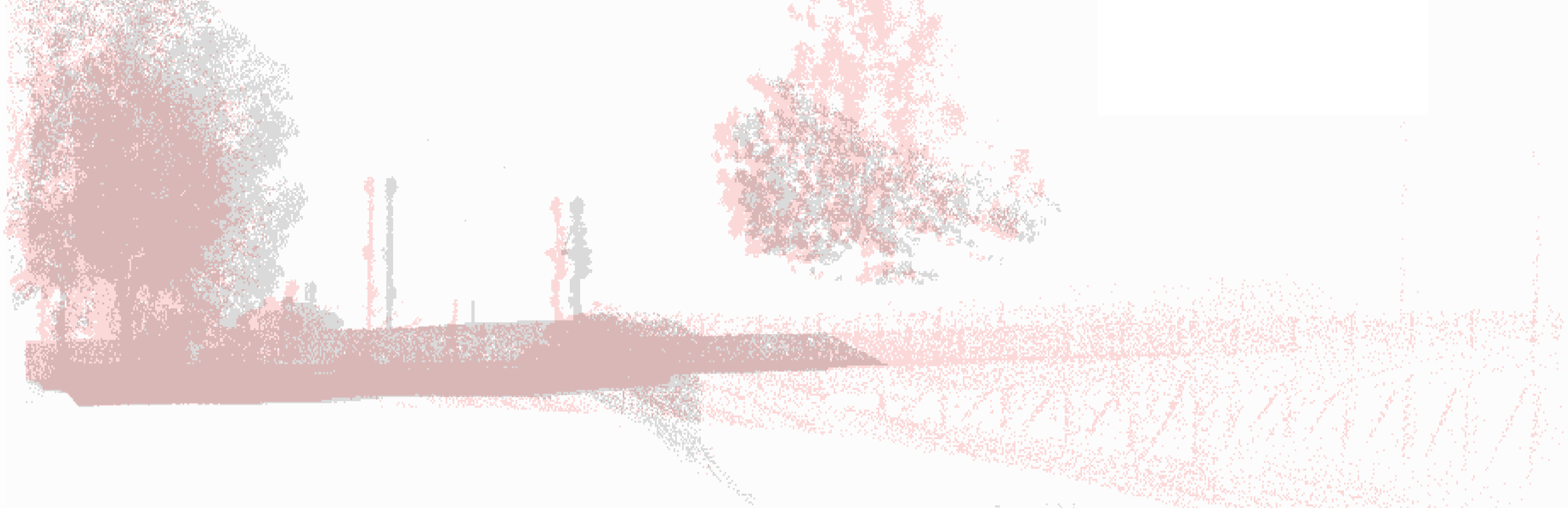


  - No big overlaps



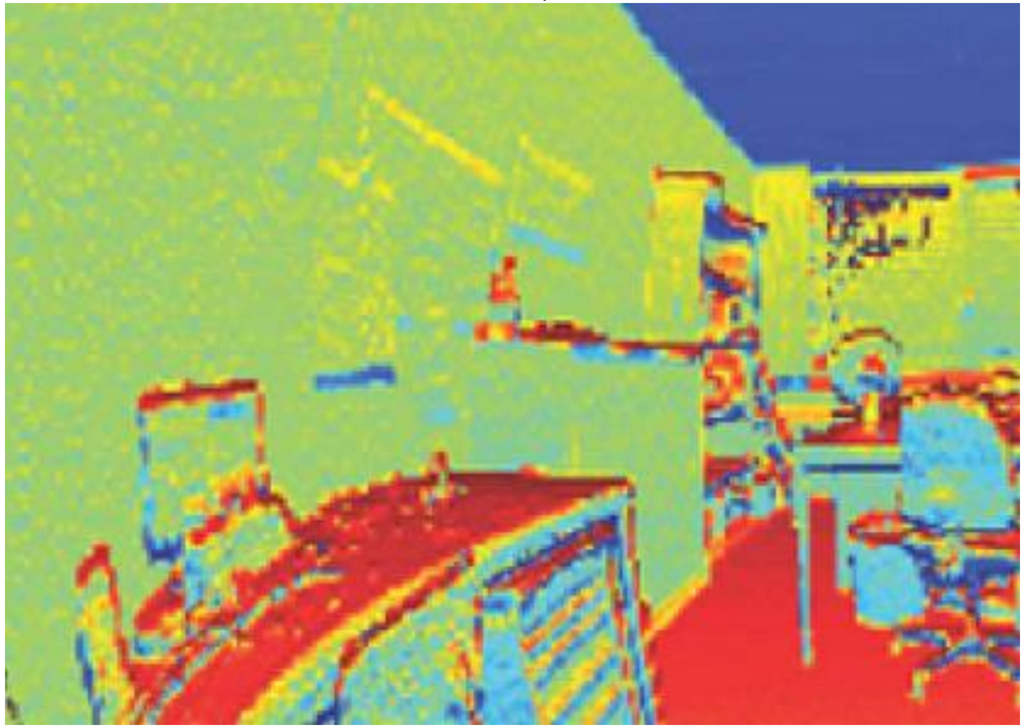
  - Large offset (~1m)

RELATED WORK: 2D LOCAL POINT CLOUD REGISTRATION



2D LOCAL POINT CLOUD REGISTRATION

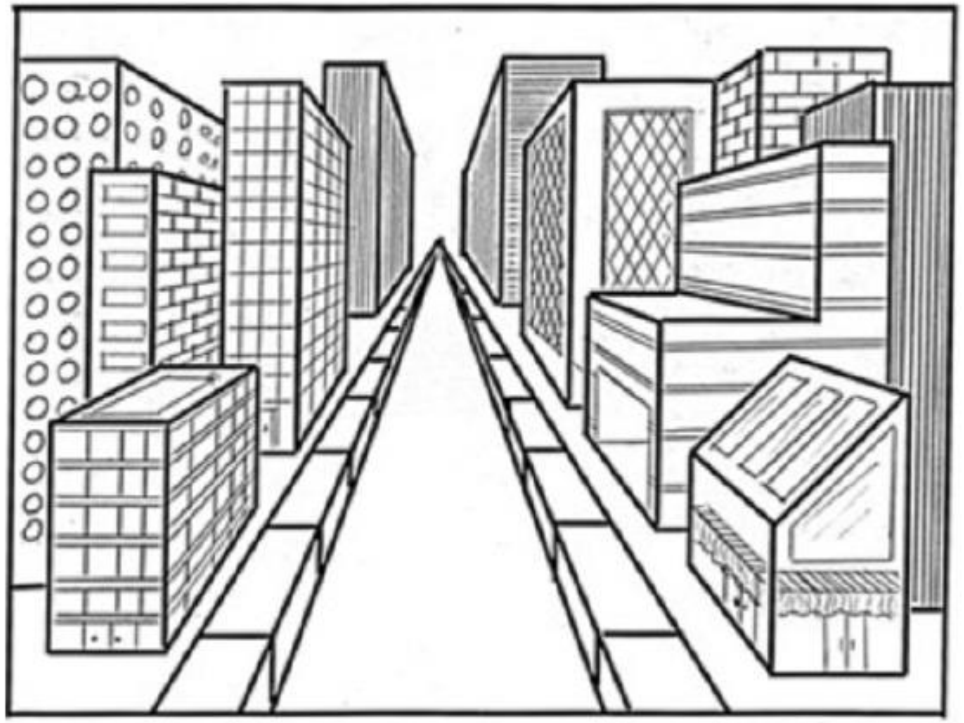
Lin et al., 2017



Bearing angle image

- Stress changes of directions

Liang et al., 2017

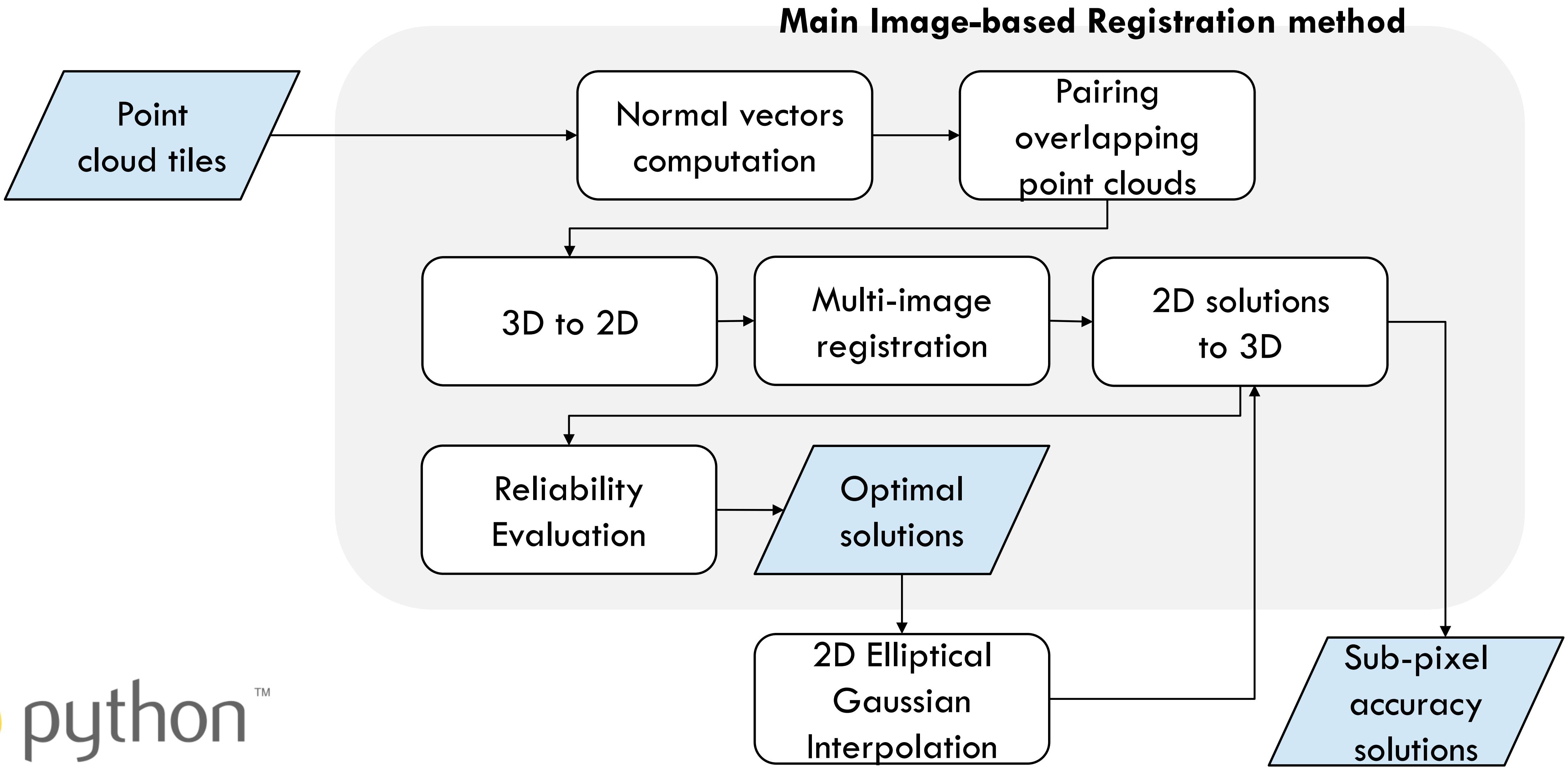


Perspective image

- What a person can see

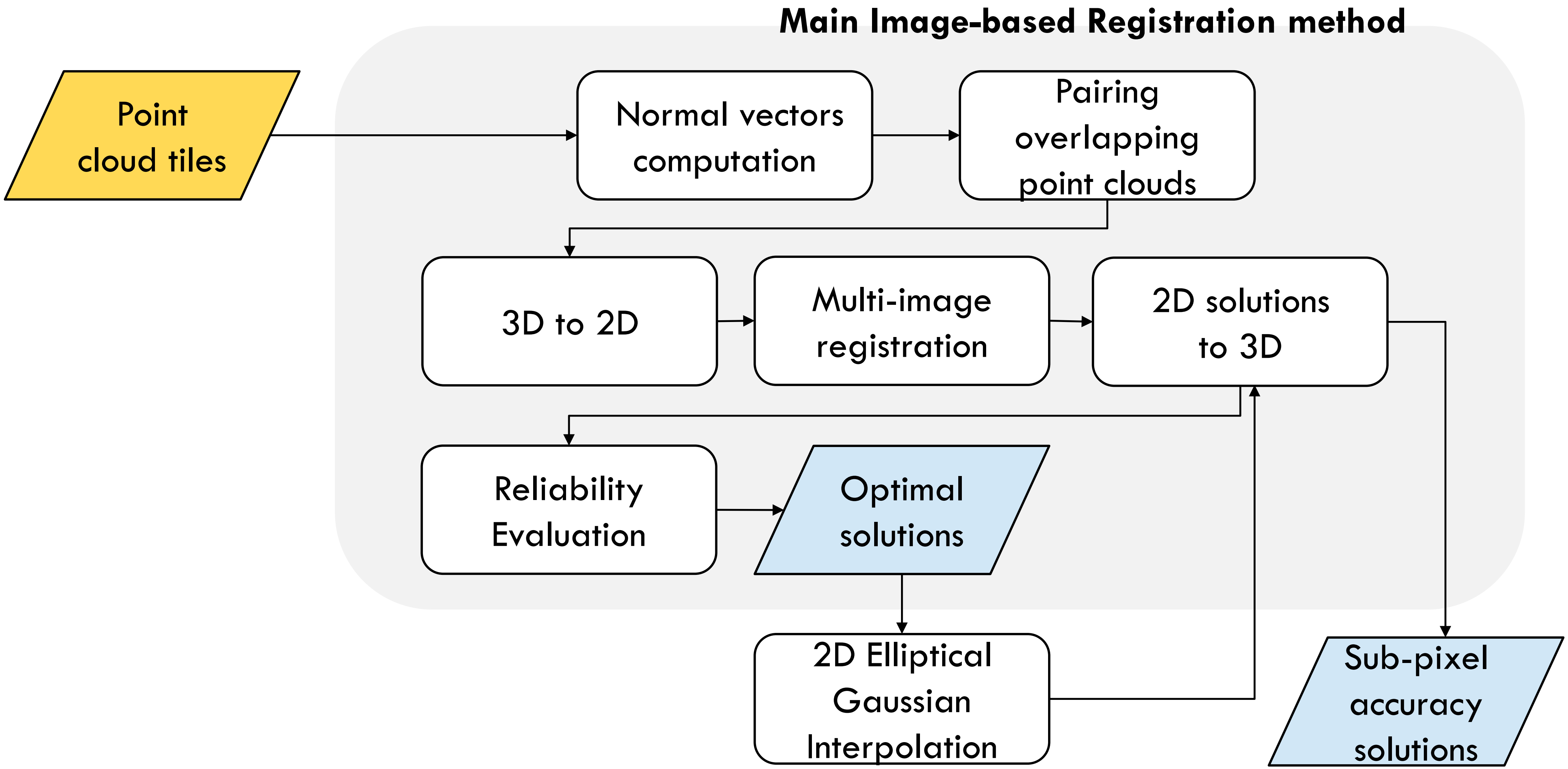
DEVELOPED IMAGE-BASED METHOD

DEVELOPED IMAGE-BASED METHOD

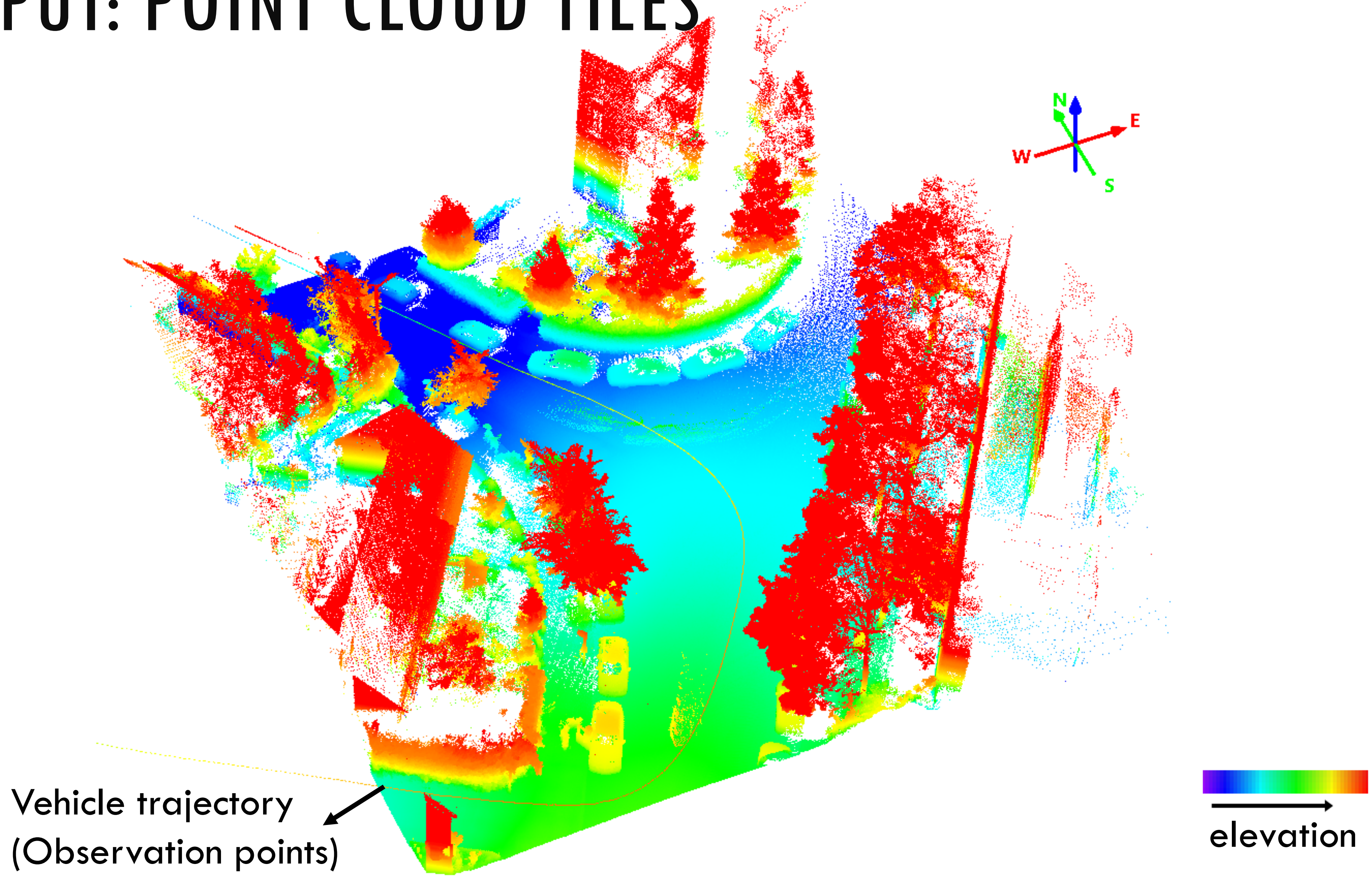


python™

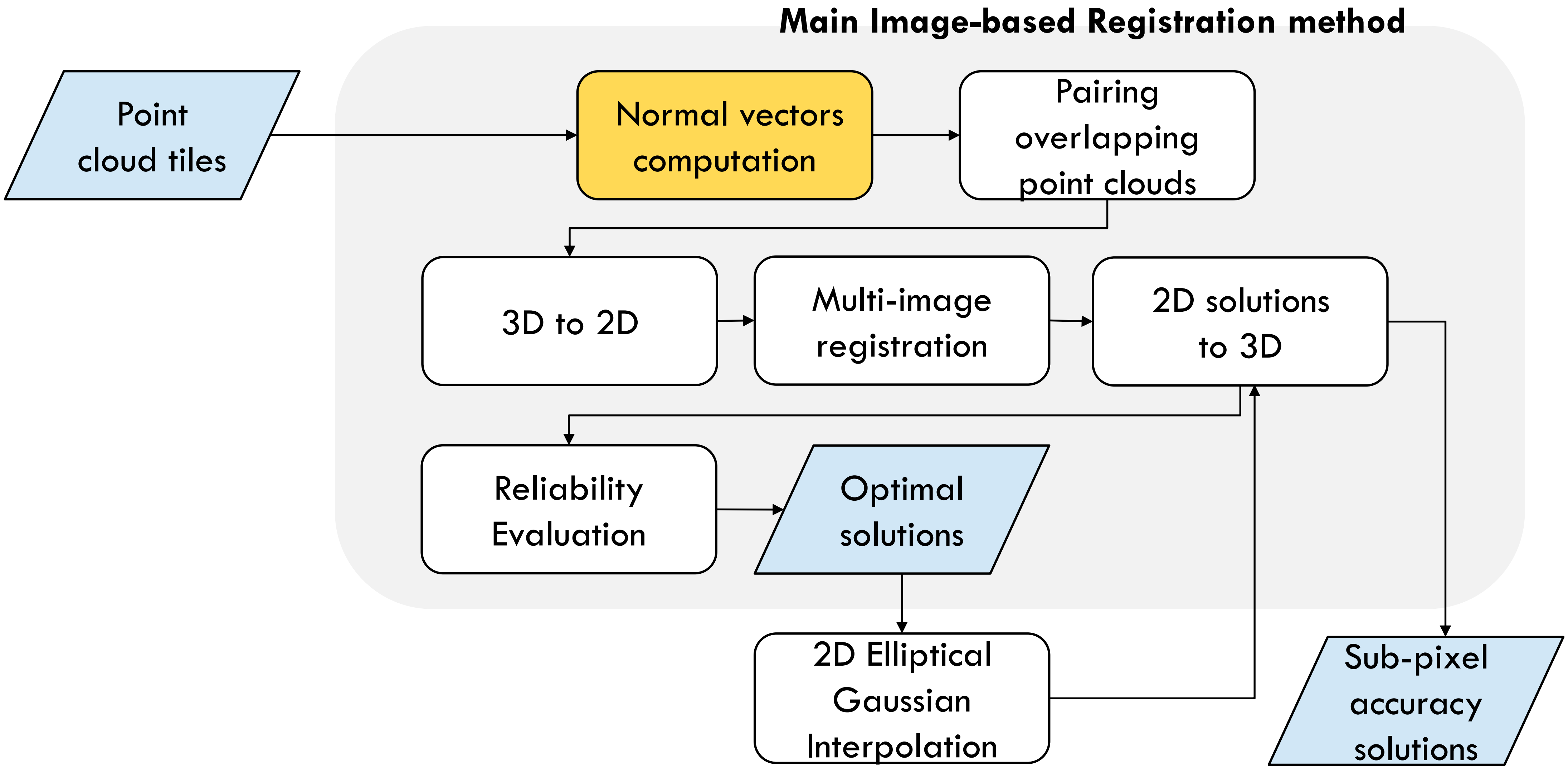
INPUT: POINT CLOUD TILES



INPUT: POINT CLOUD TILES

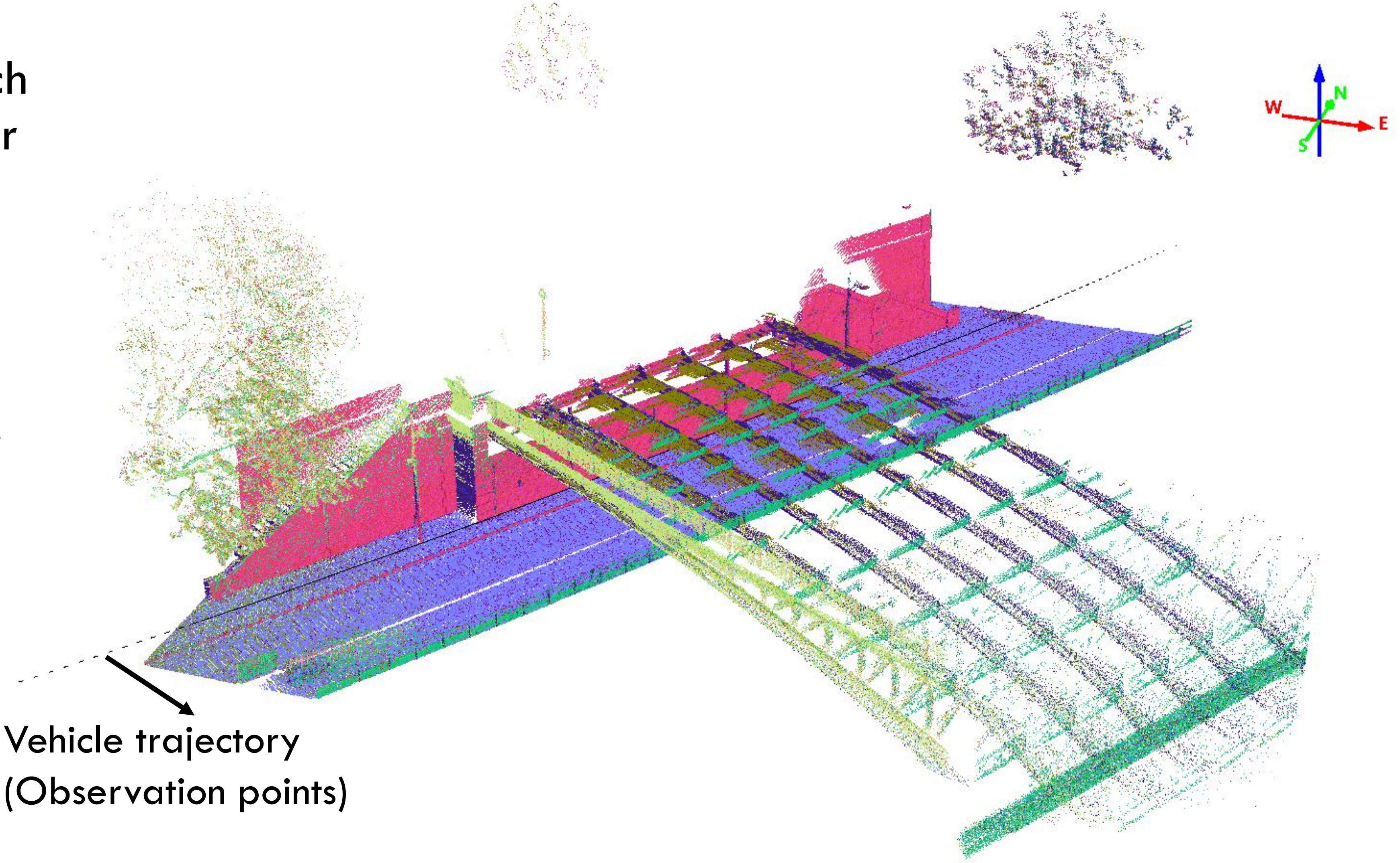


1. NORMAL VECTORS COMPUTATION

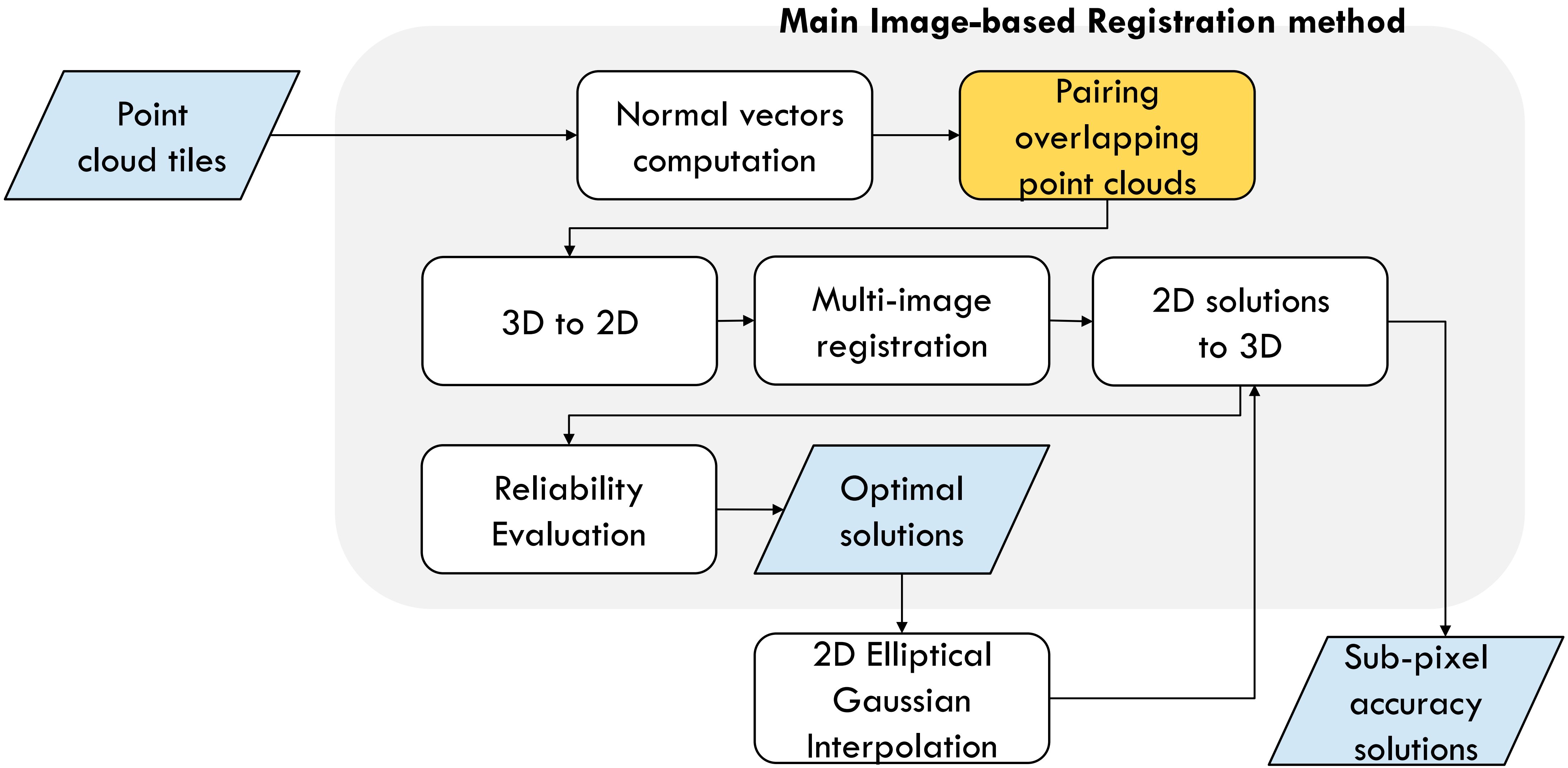


NORMAL VECTORS COMPUTATION

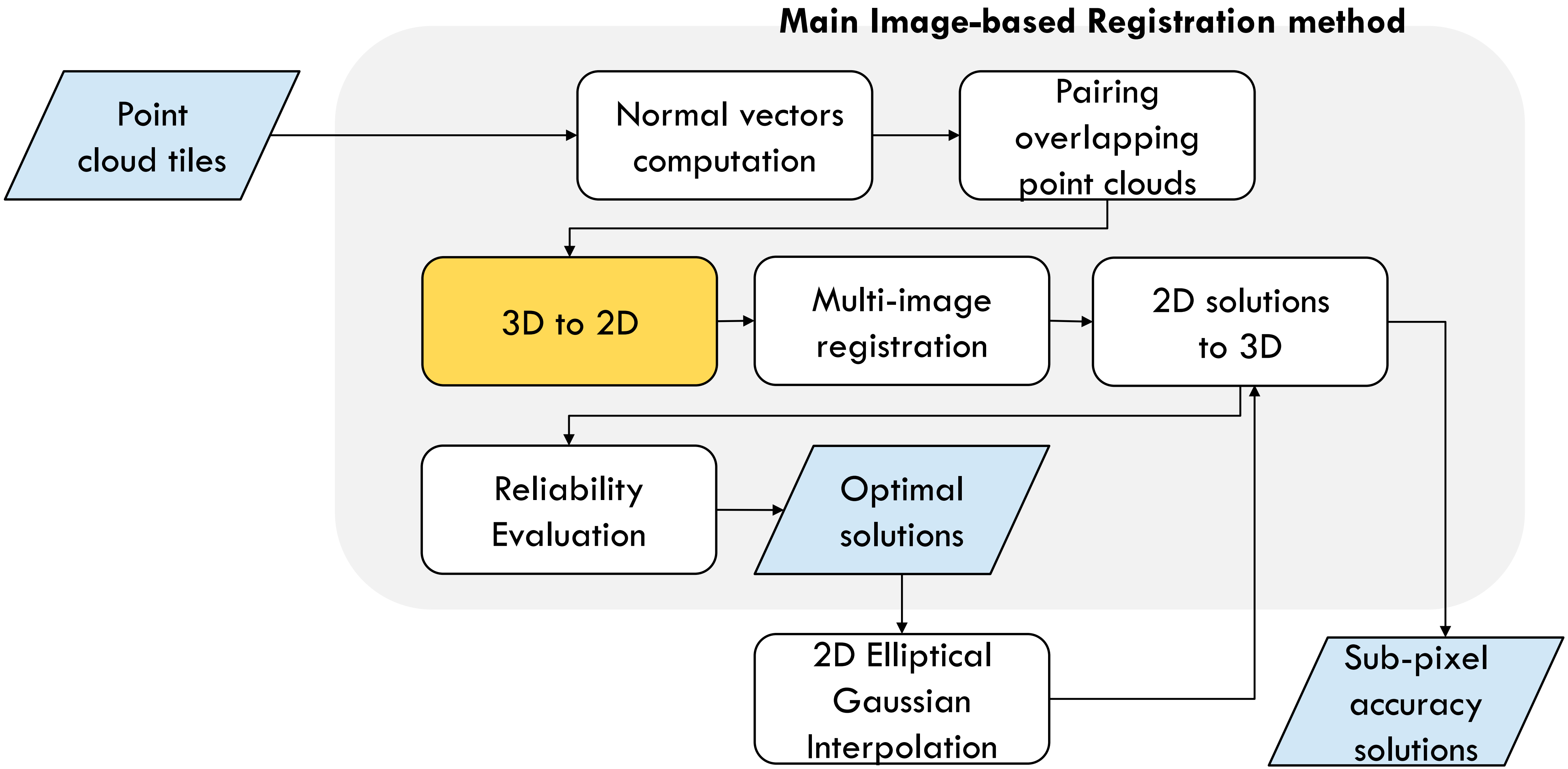
- Normal vector of each point = perpendicular vector to a fitted plane around an observed point
- To make the normal vectors consistent: use of trajectory points
- Surfaces' orientation



PAIRING OVERLAPPING POINT CLOUDS

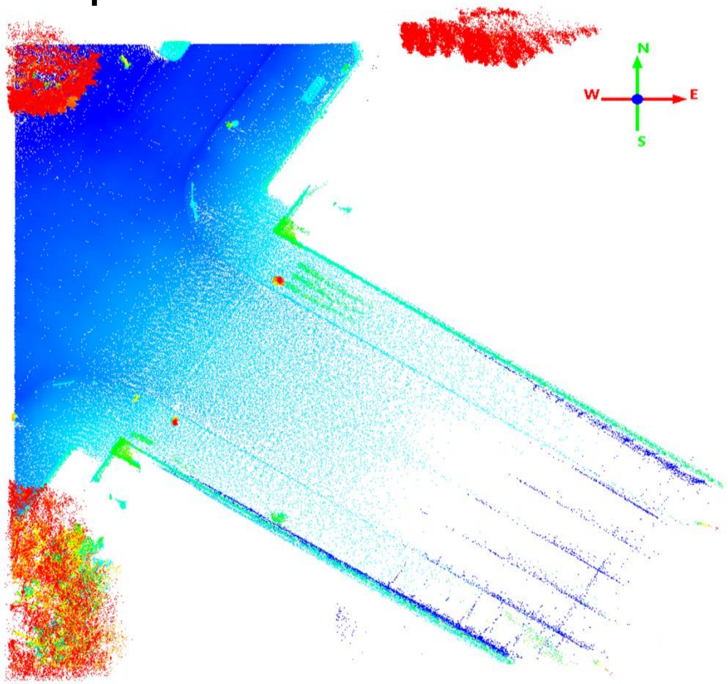


3D TO 2D

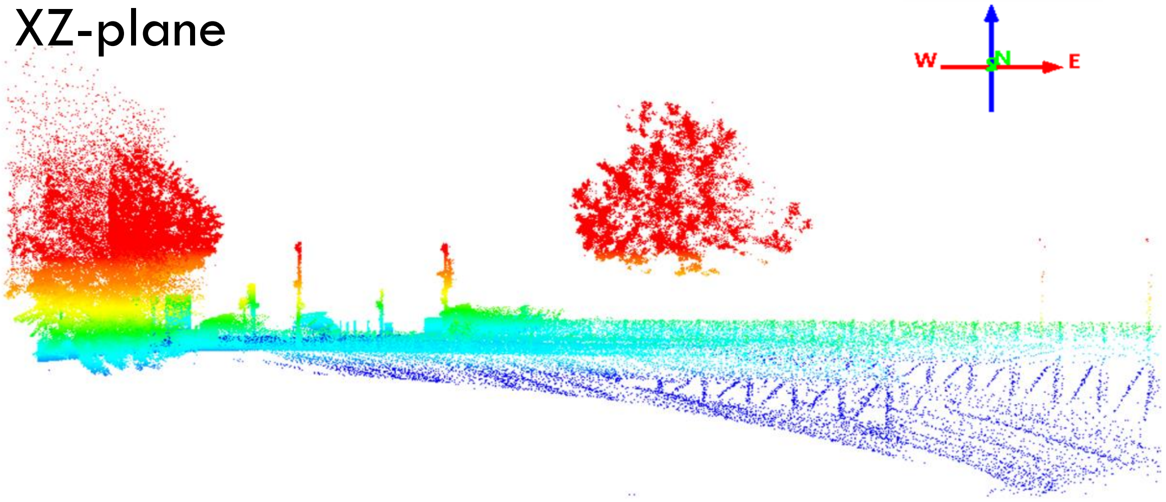

Main Image-based Registration method
Point cloud tiles
Normal vectors computation
Pairing overlapping point clouds
3D to 2D
Multi-image registration
2D solutions to 3D
Reliability Evaluation
Optimal solutions
2D Elliptical Gaussian Interpolation
Sub-pixel accuracy solutions

3D TO 2D: REDUCTION OF DIMENSIONS (1) : MAIN EXAMPLE

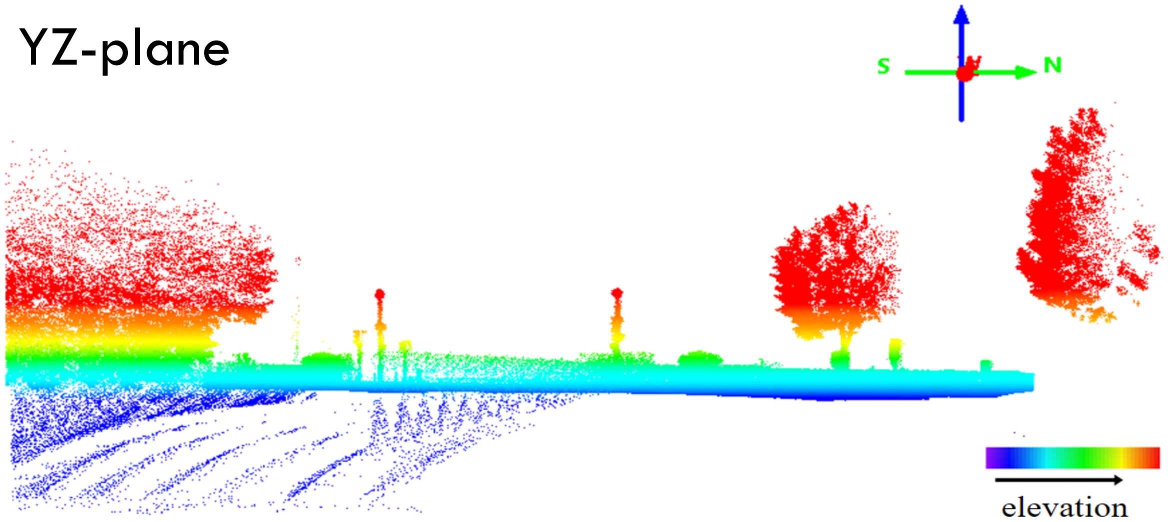
XY-plane



XZ-plane

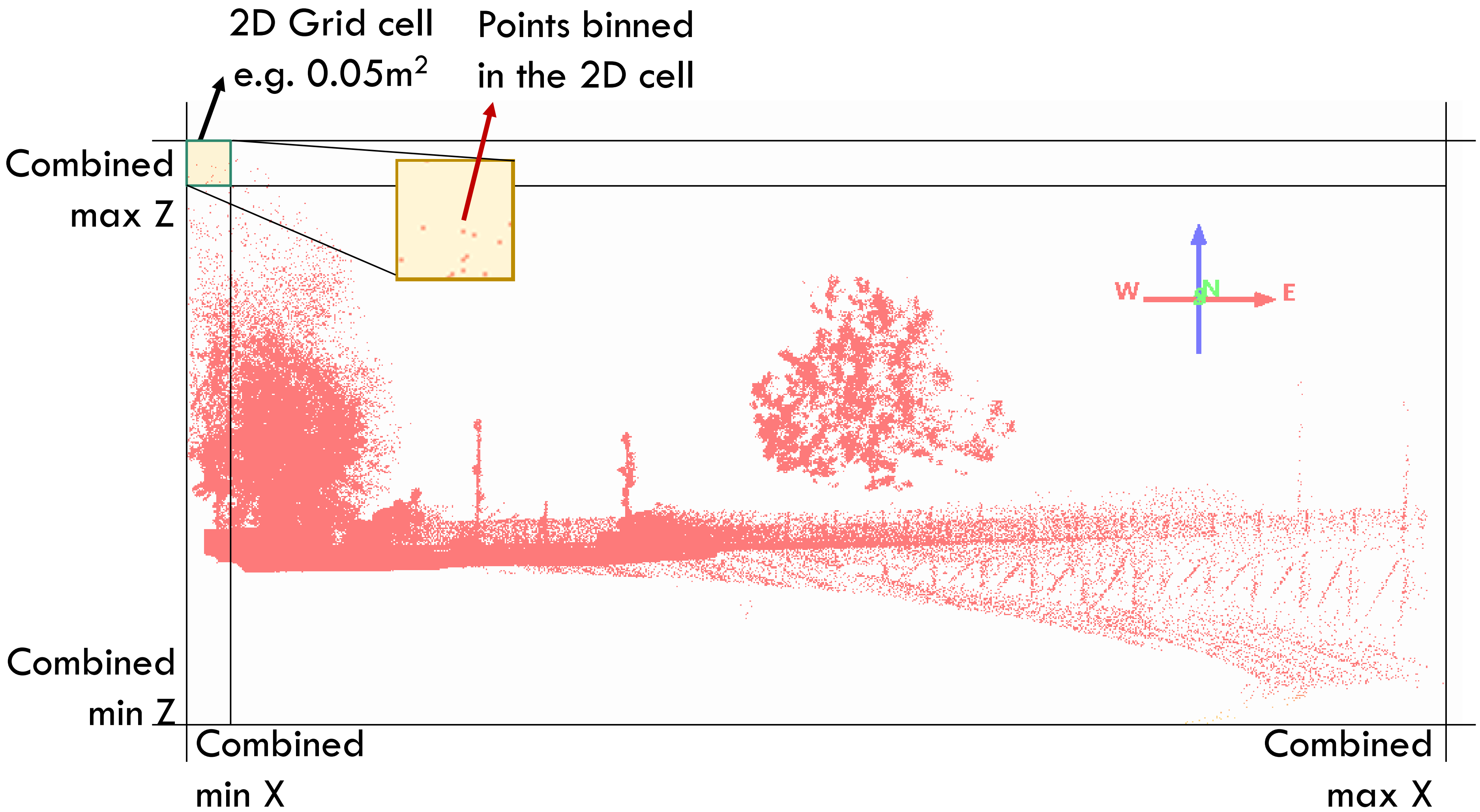


YZ-plane



3D TO 2D: REDUCTION OF DIMENSIONS (1)

- 2D grid creation **based** on the two dimensions of each **plane**
- **Spatial binning** of points into 2D grid cells

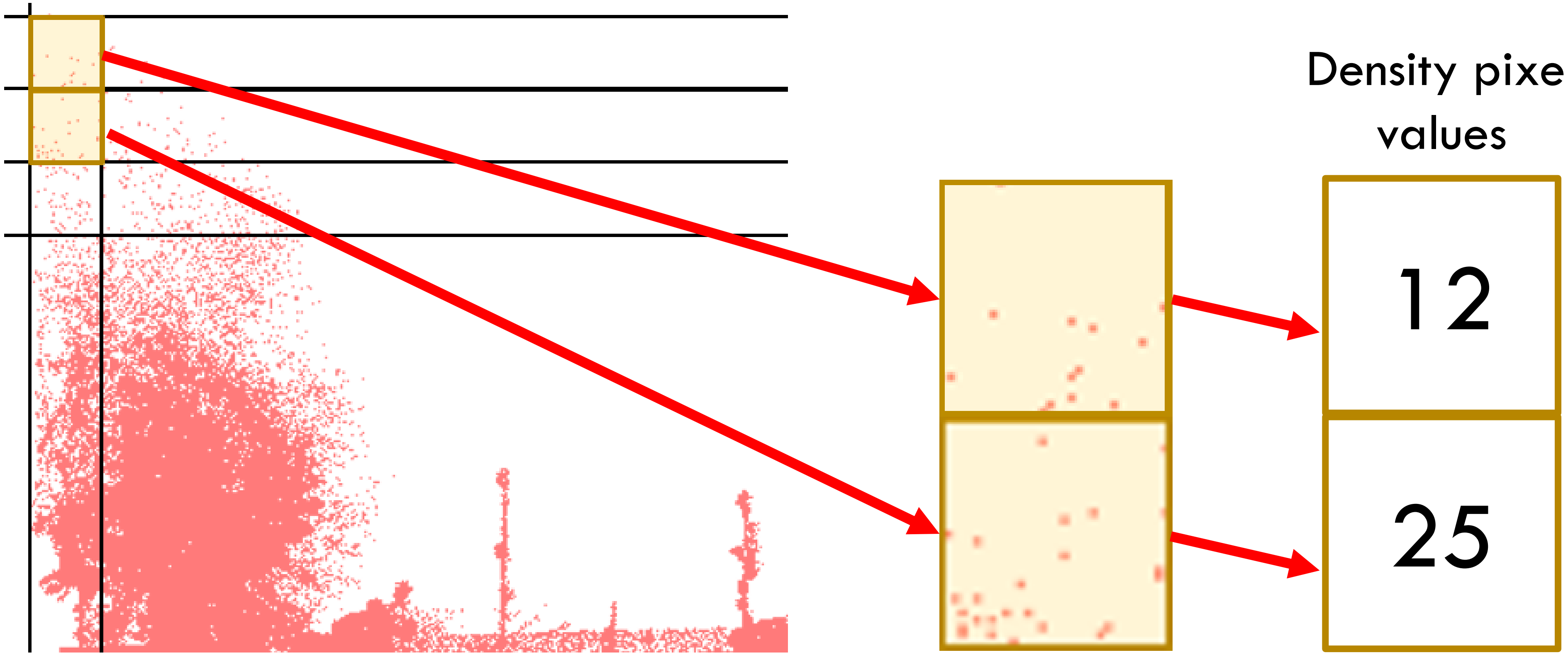


3D TO 2D: ASSIGNING VALUES TO THE 2D CELLS (2)

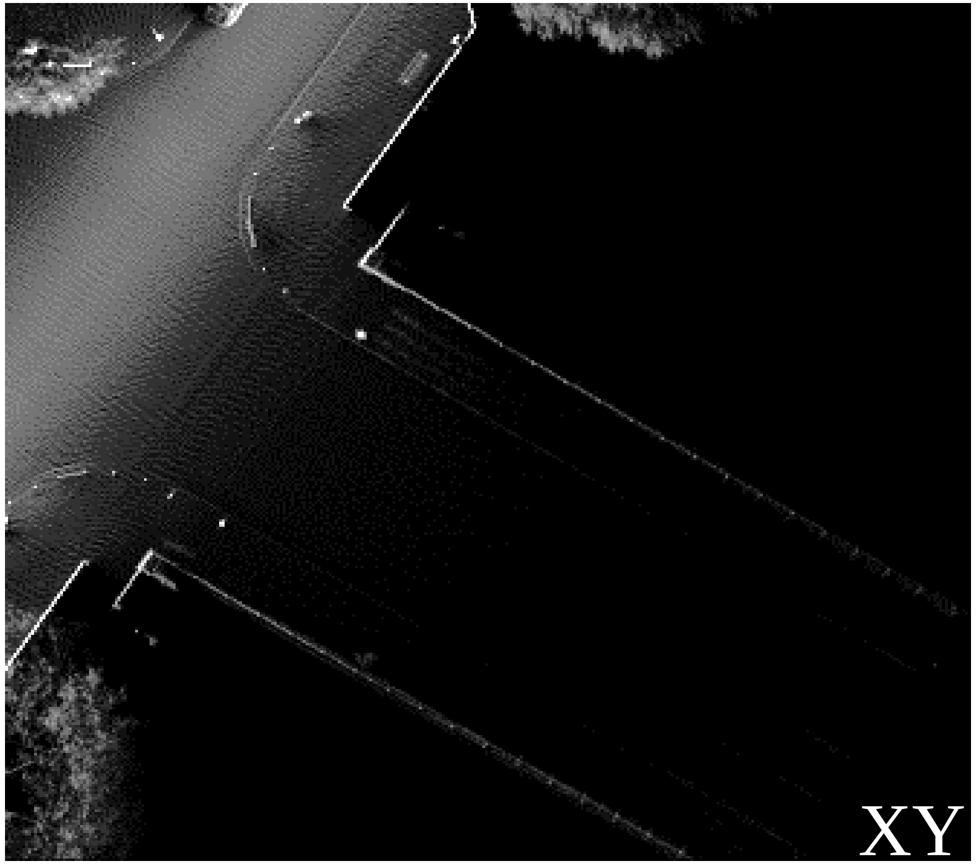
- Different attributes of points→ Different image types

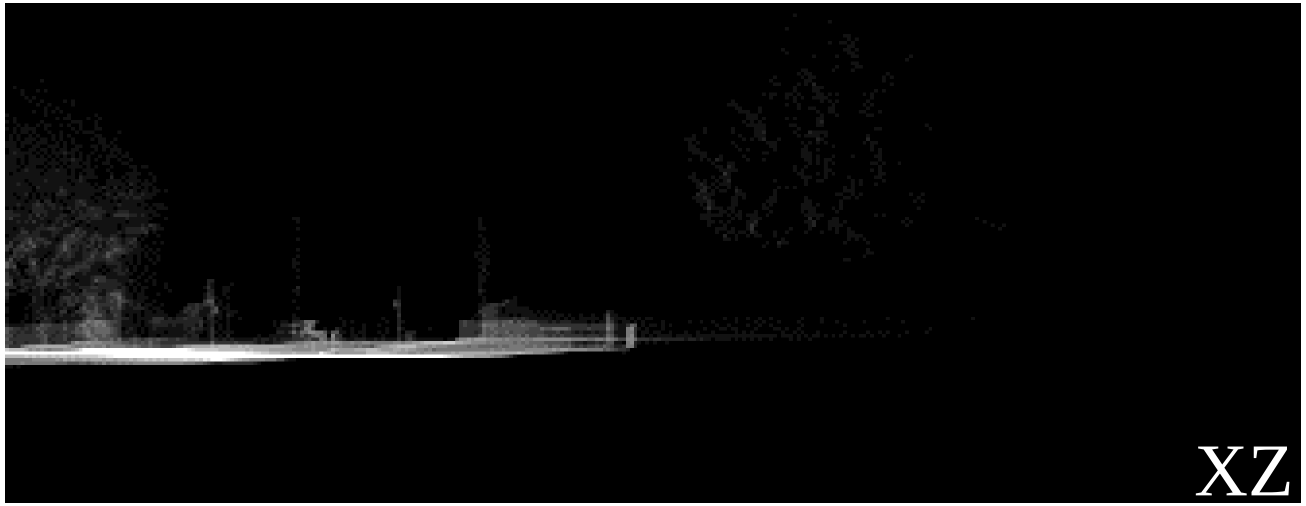
3D TO 2D: DENSITY

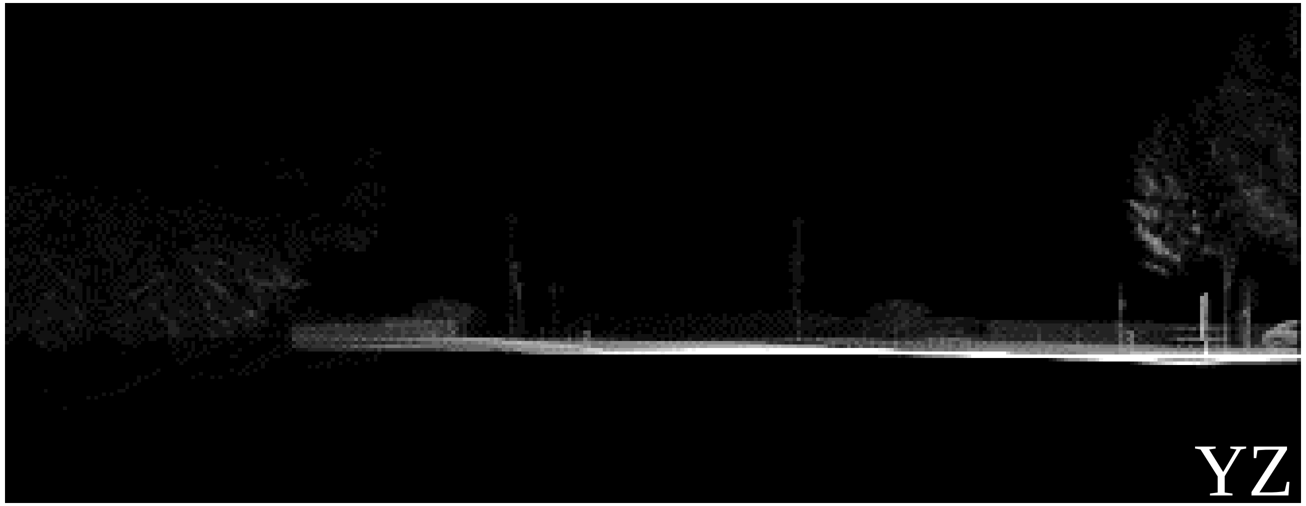
- DENSITY



3D TO 2D: DENSITY







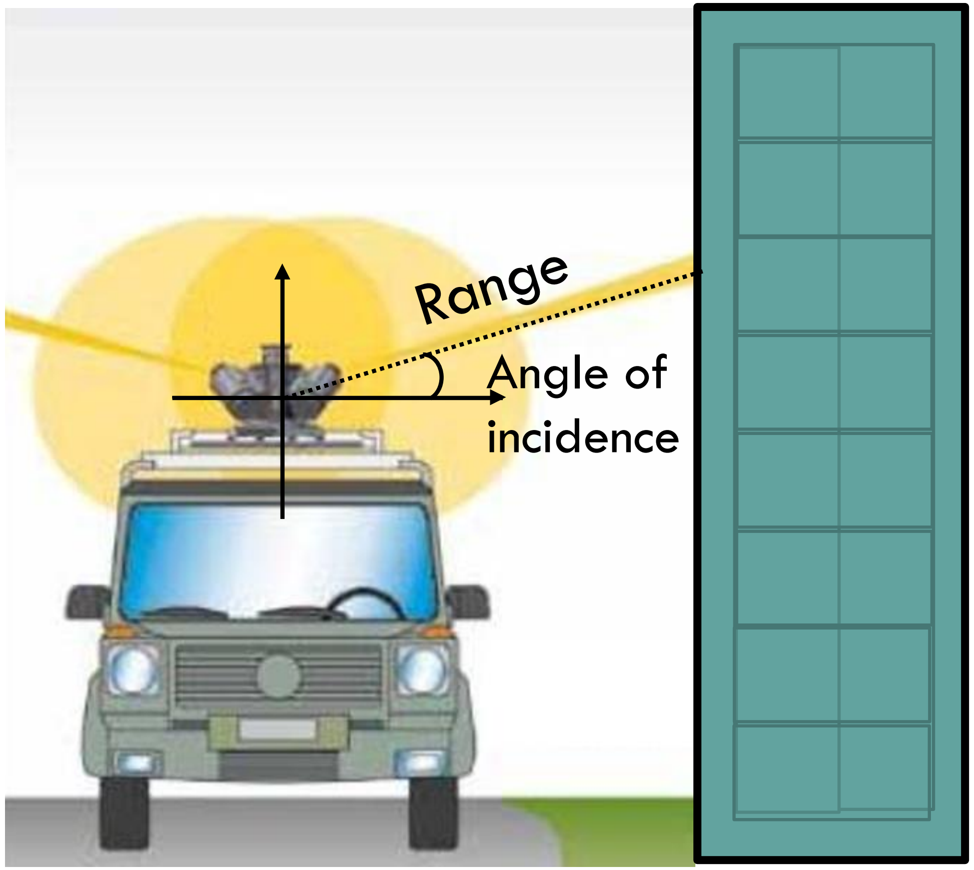
3D TO 2D: INTENSITY

- INTENSITY: **strength** of the **backscattered signal**

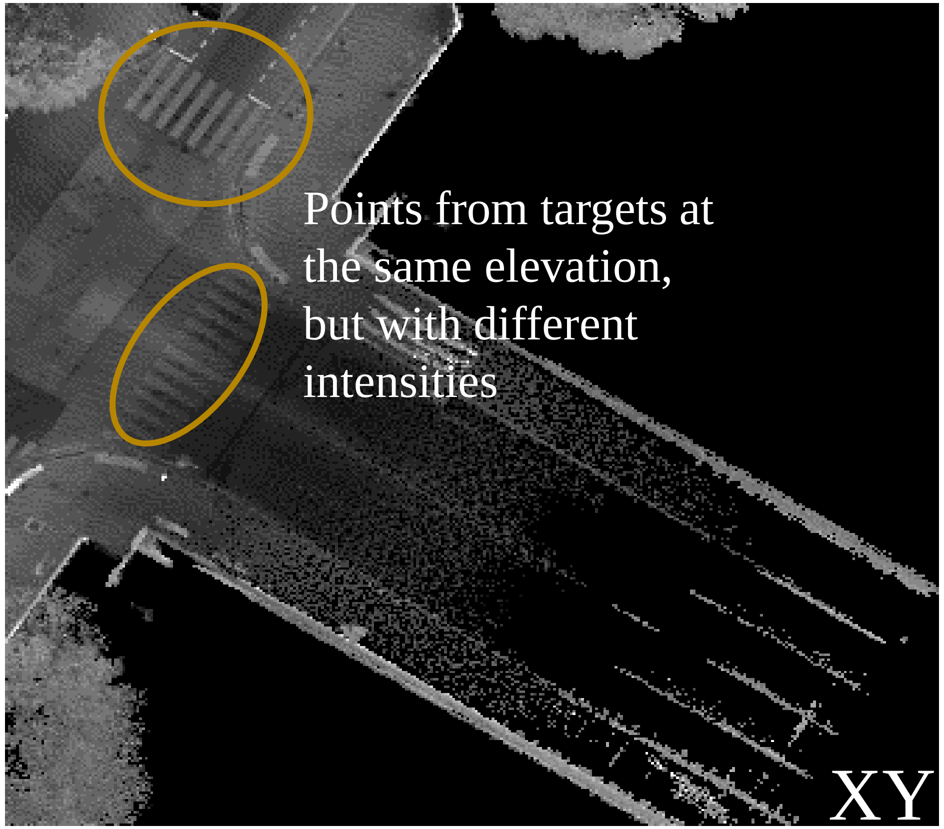
Range: scanning system - object

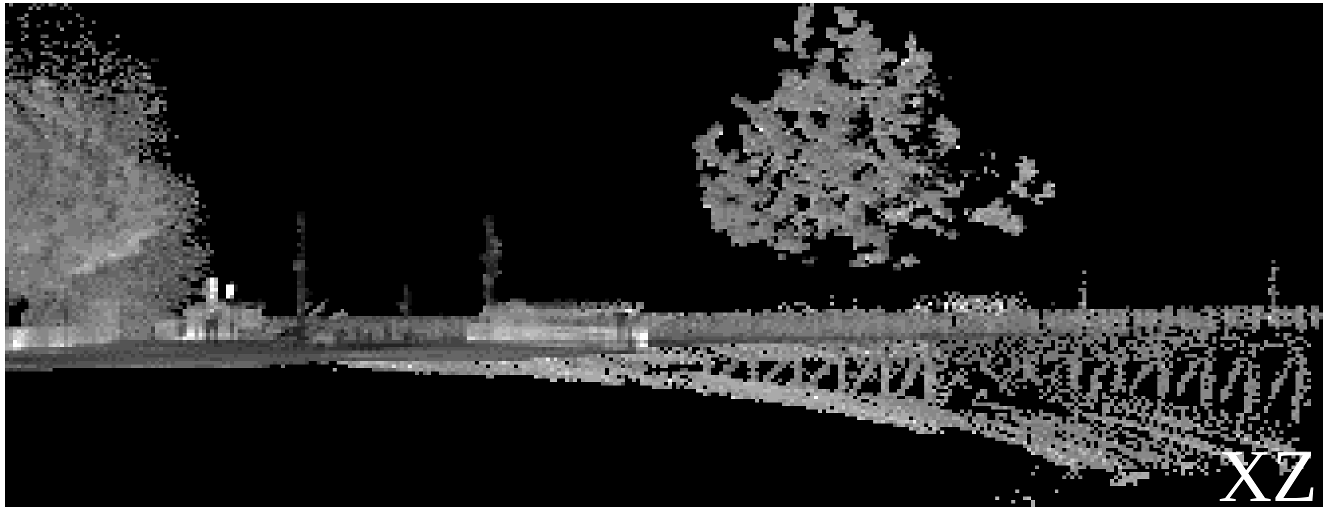
Object's **reflectivity**

Angle of incidence : scanning system – object

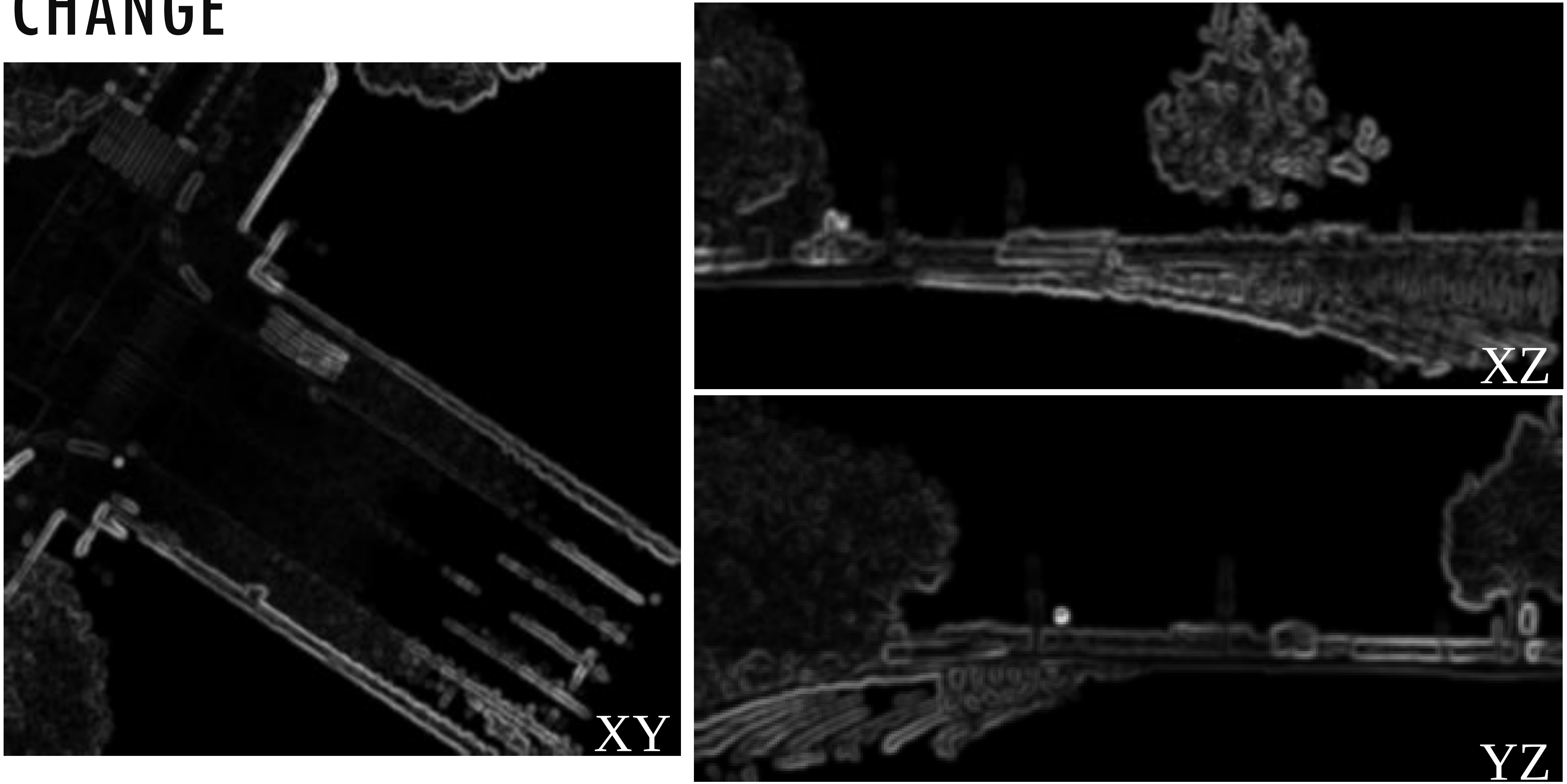


3D TO 2D: INTENSITY

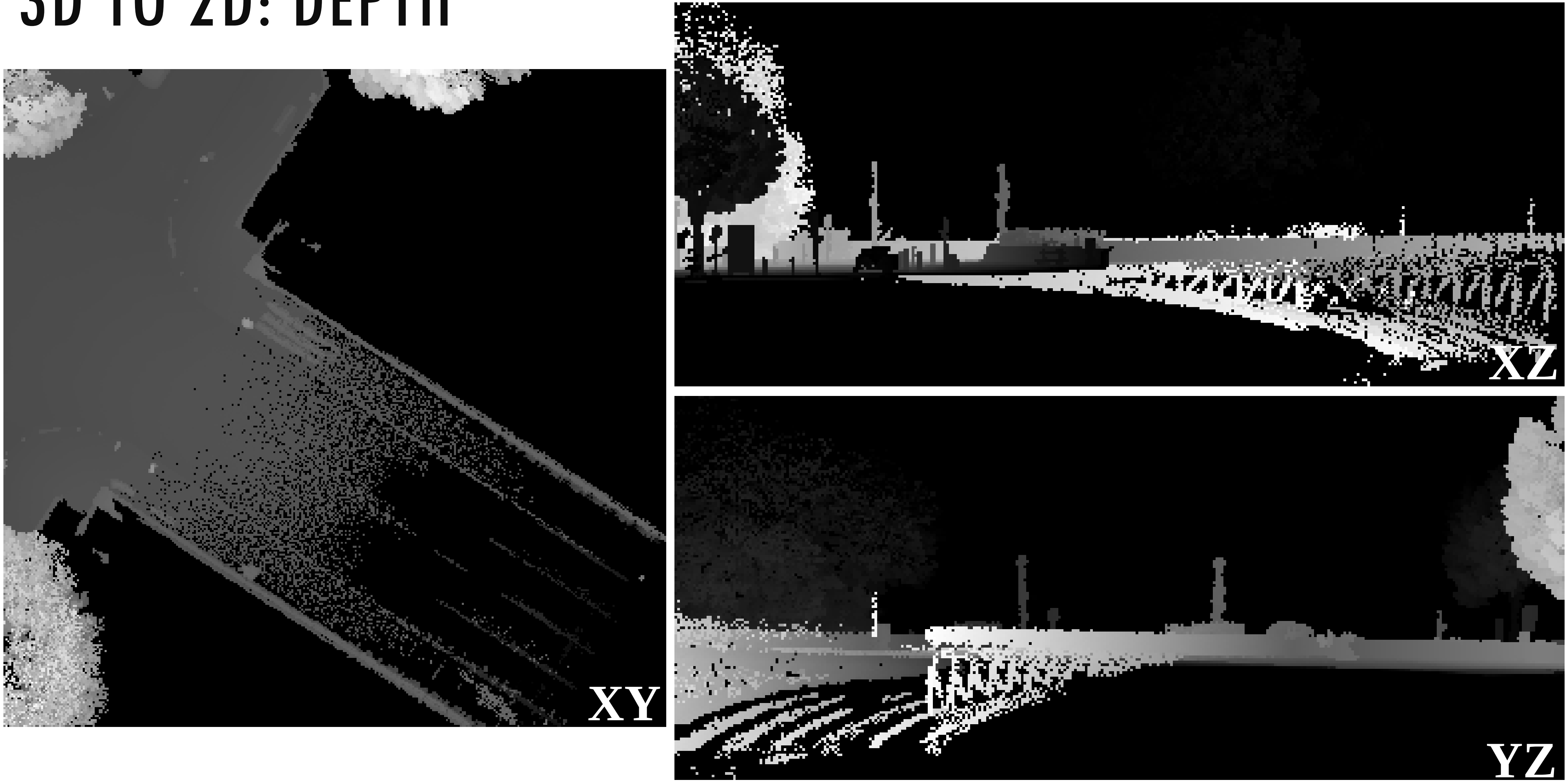




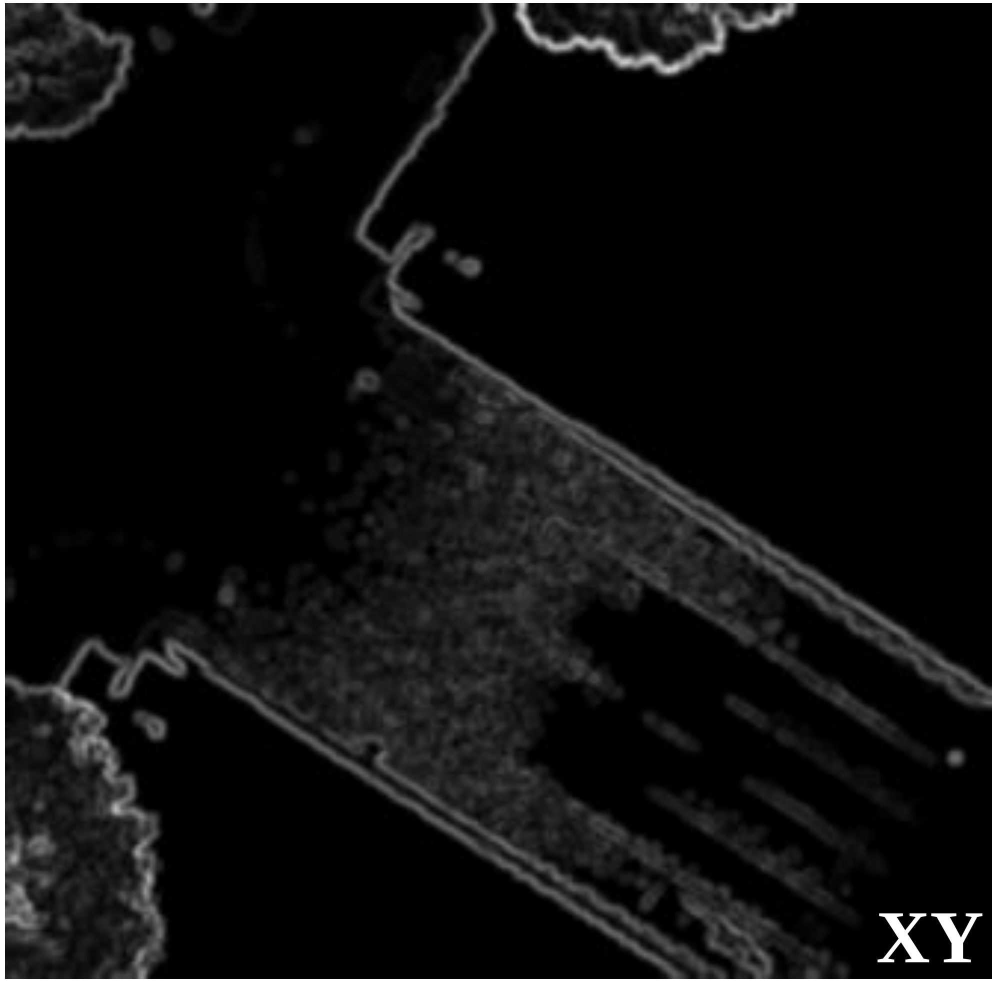
3D TO 2D: INTENSITY GRADIENT: RATE OF INTENSITY VALUES CHANGE

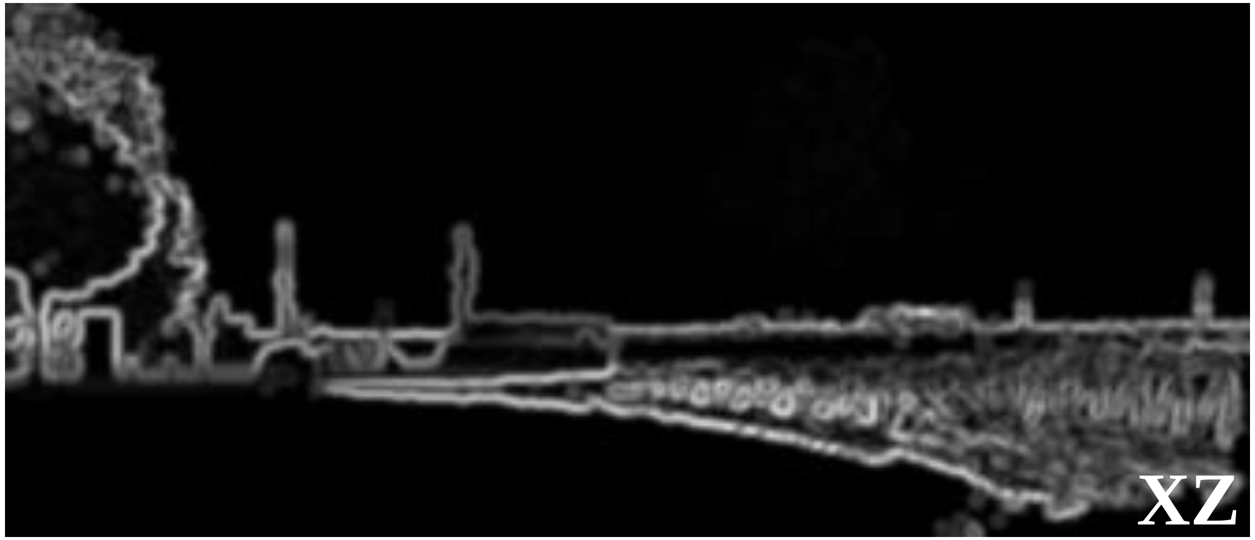


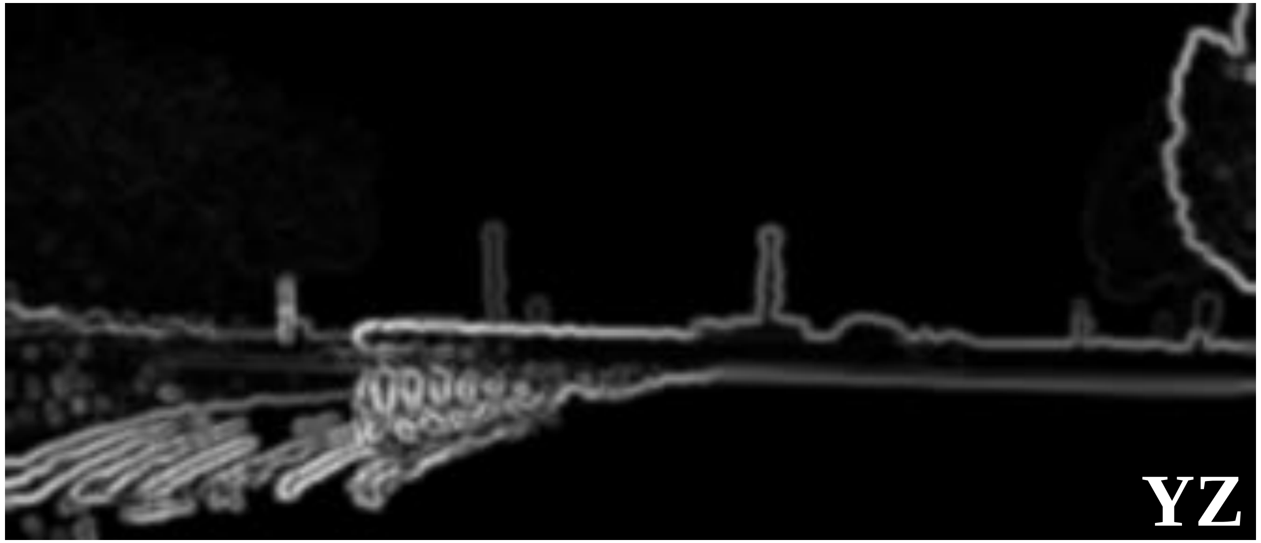
3D TO 2D: DEPTH



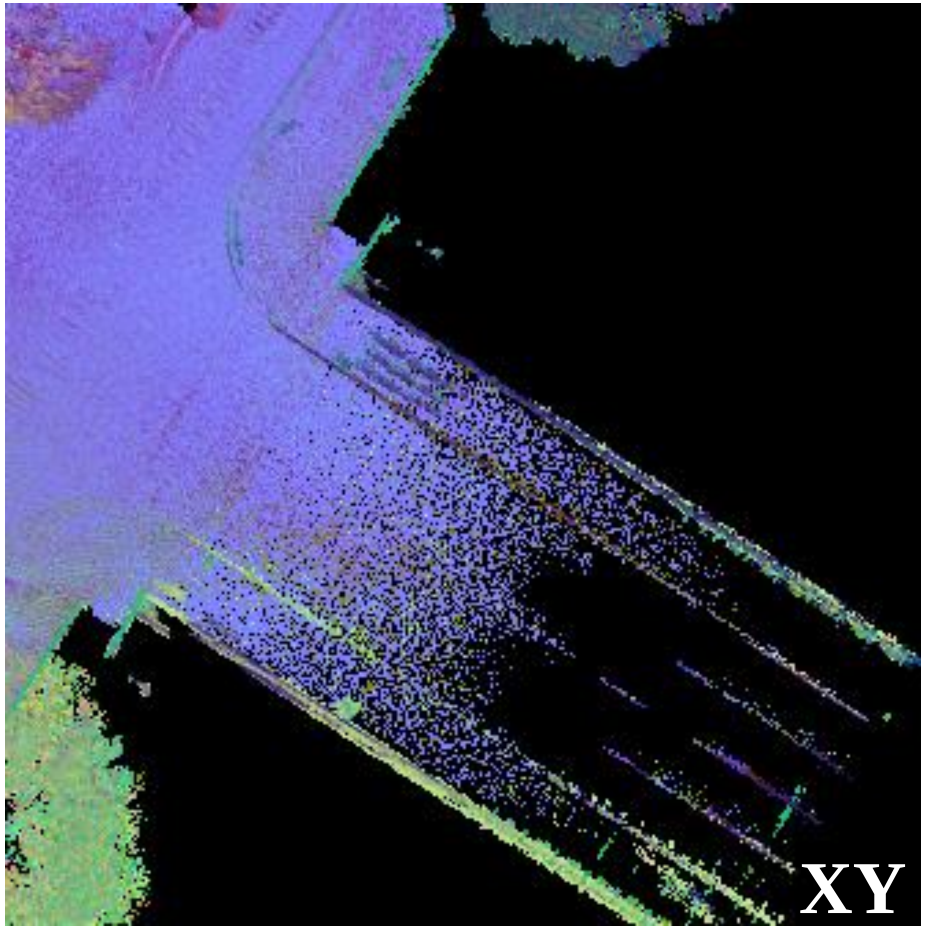
3D TO 2D: DEPTH GRADIENT: RATE OF DEPTH VALUES CHANGE

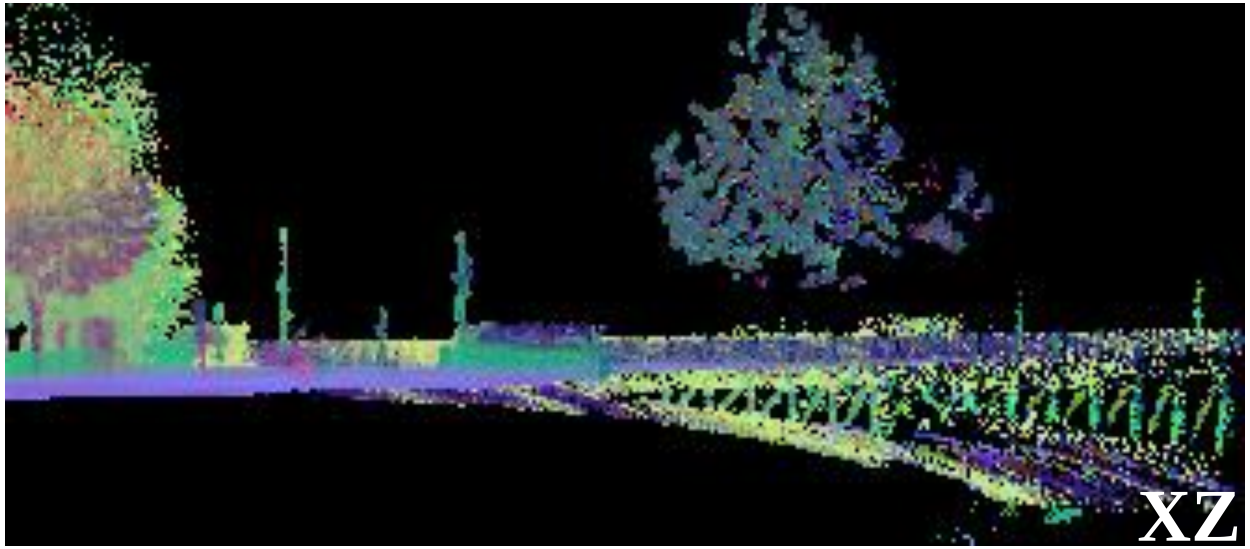






3D TO 2D: NORMAL VECTORS: ORIENTATION OF SURFACES





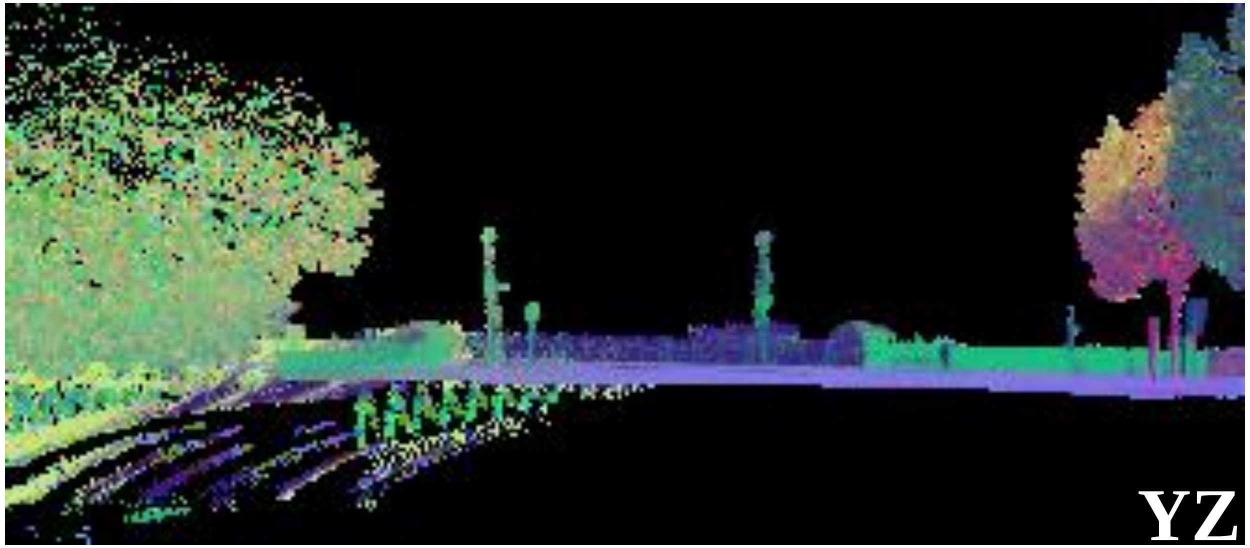


IMAGE PAIRWISE REGISTRATION

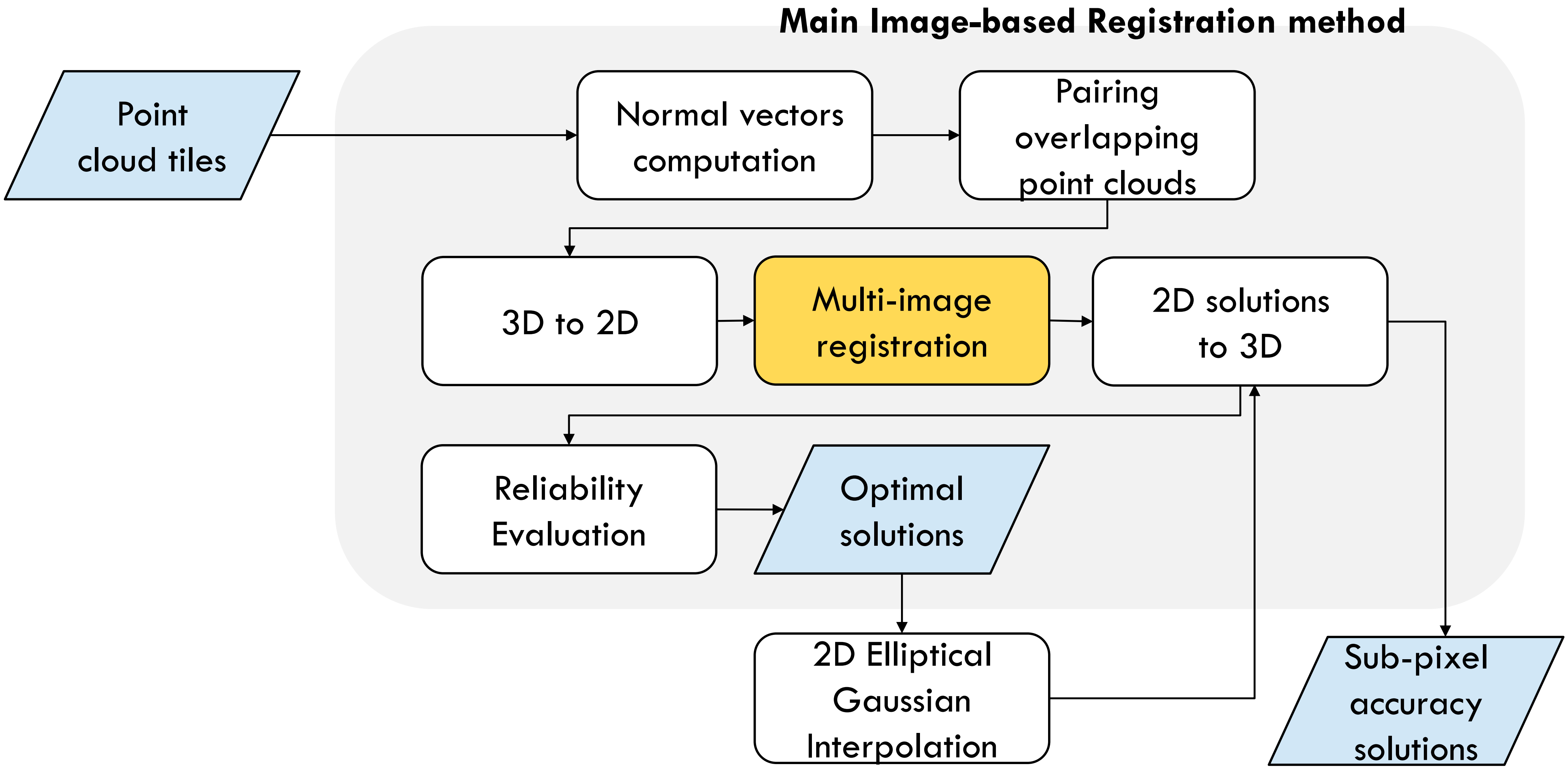
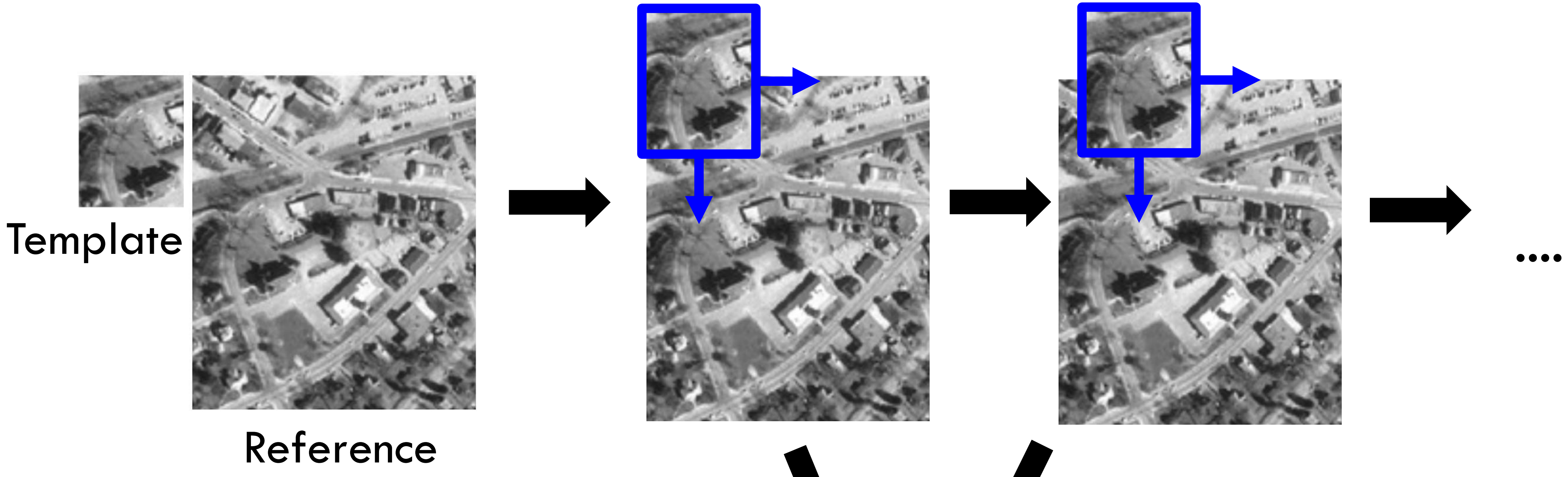
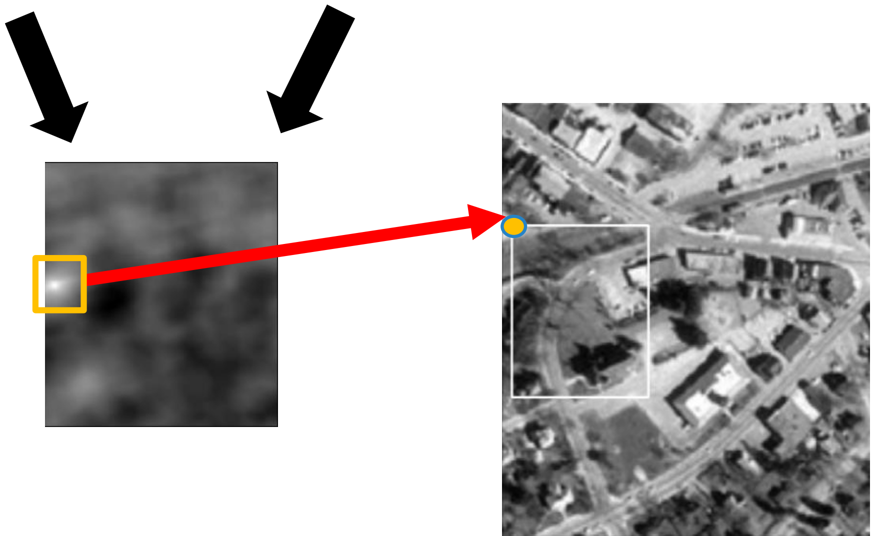


IMAGE PAIRWISE REGISTRATION: TEMPLATE MATCHING

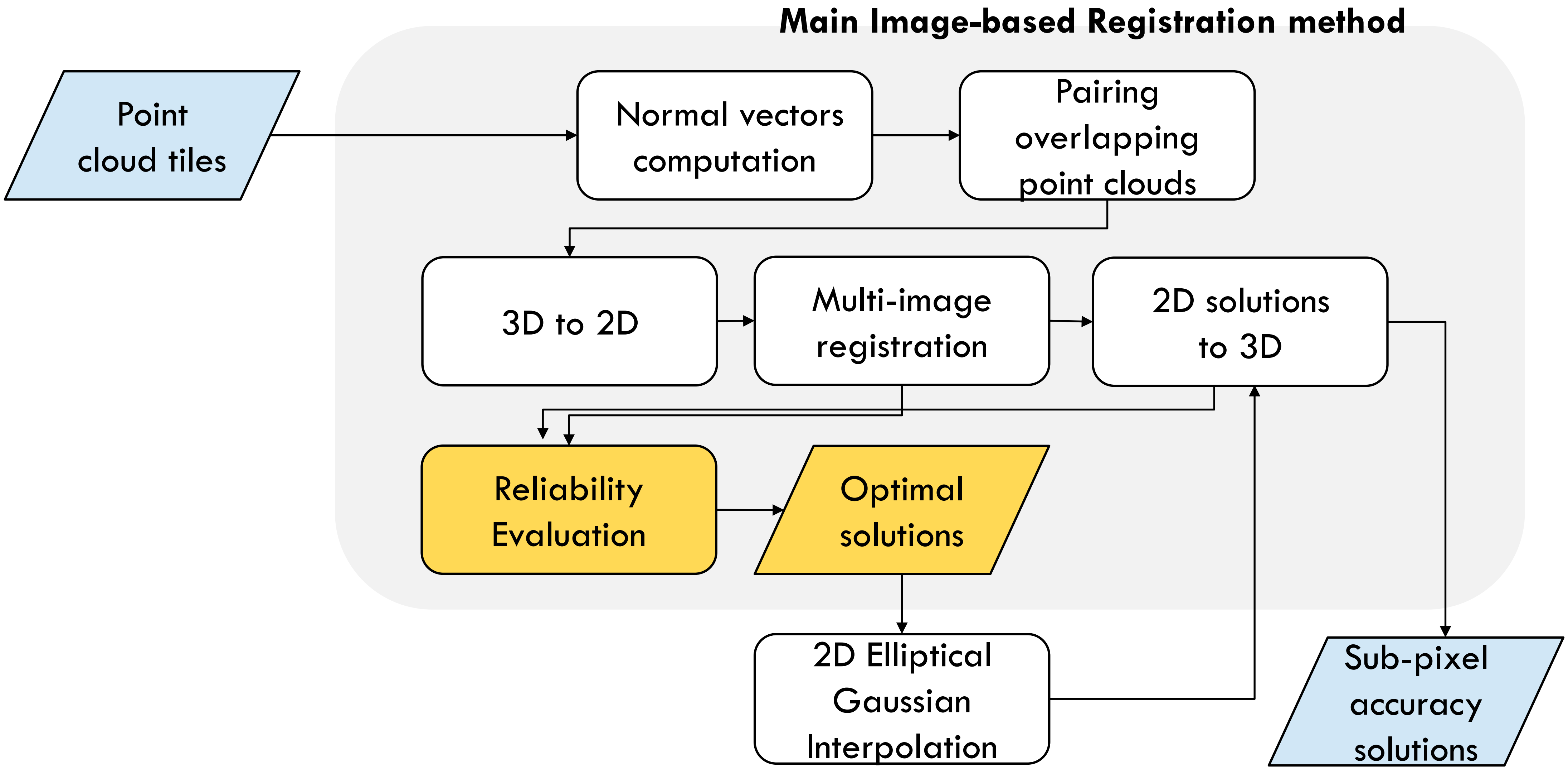


Similarity score map

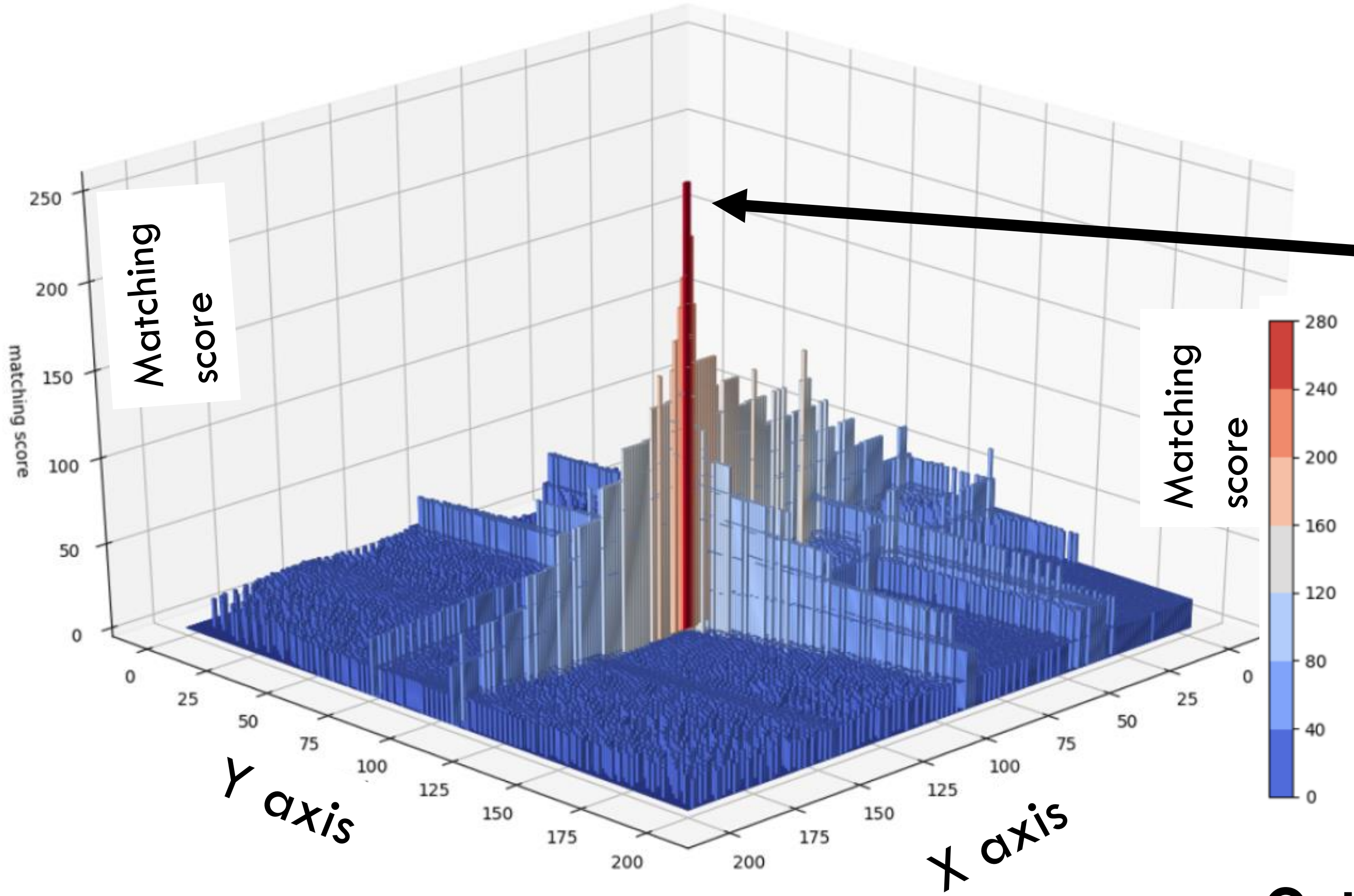
2D array that contains similarity scores



RELIABILITY EVALUATION & OPTIMAL SOLUTIONS



RELIABILITY EVALUATION & OPTIMAL SOLUTIONS



XY Similarity scores map visualized in 3D

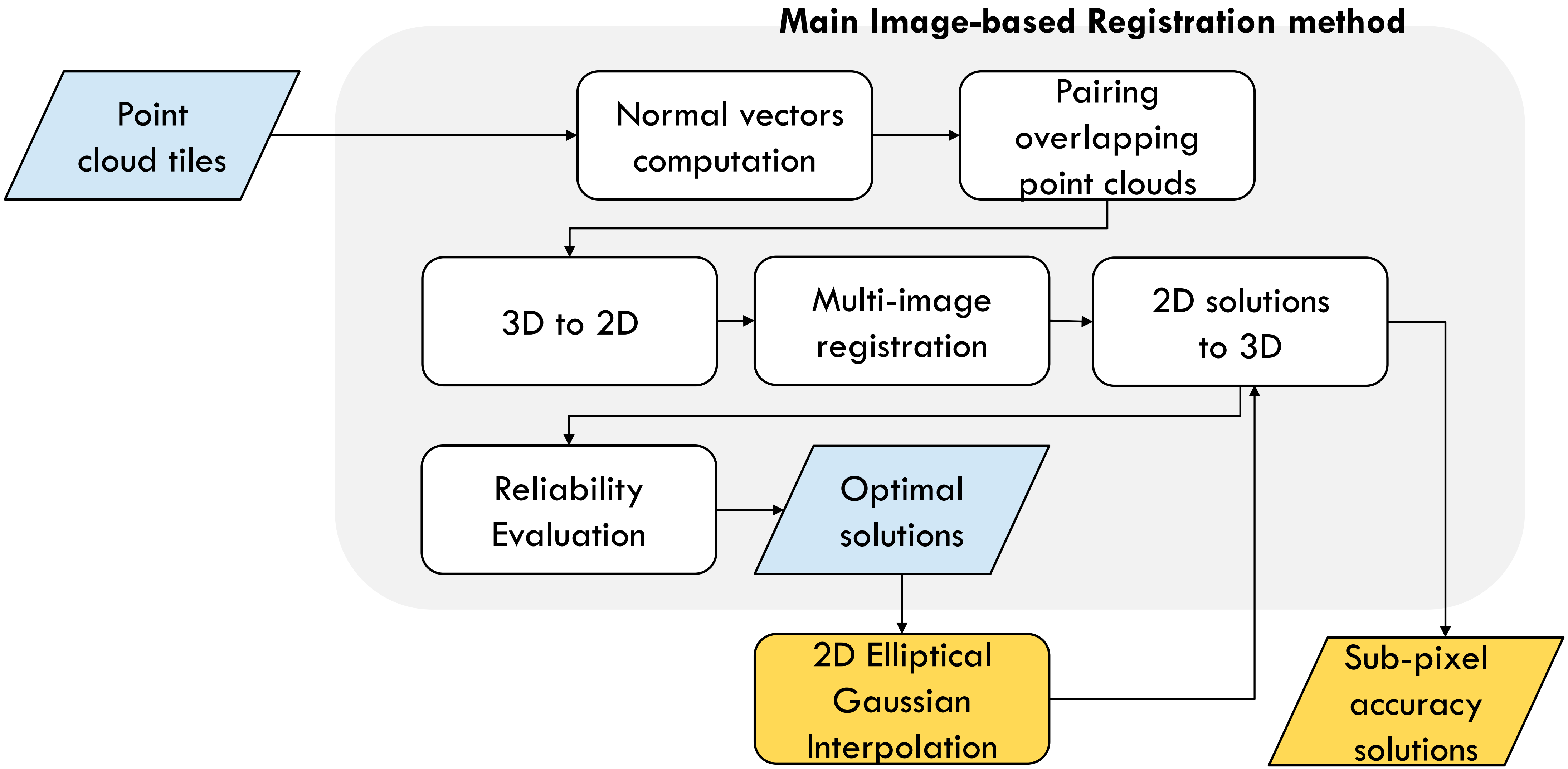
Evaluation of strength and uniqueness of the highest similarity values

Score map accepted → Matching accepted

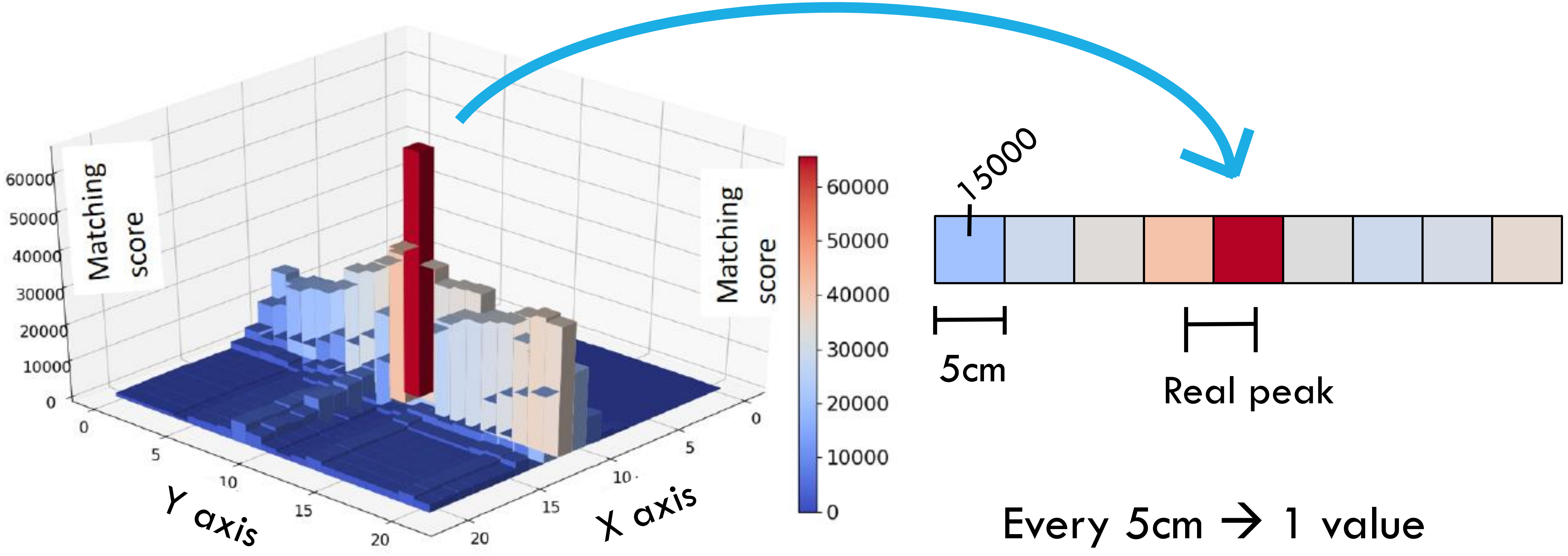
Score map rejected → Matching rejected

Optimal X = mean (accepted x values)

IMAGE PAIRWISE REGISTRATION



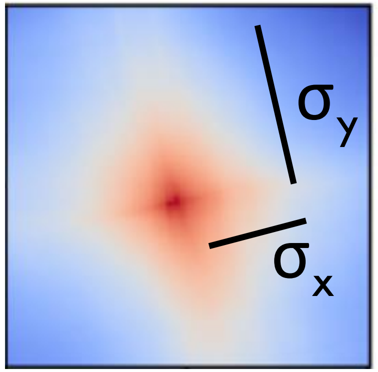
SUB-PIXEL ACCURACY

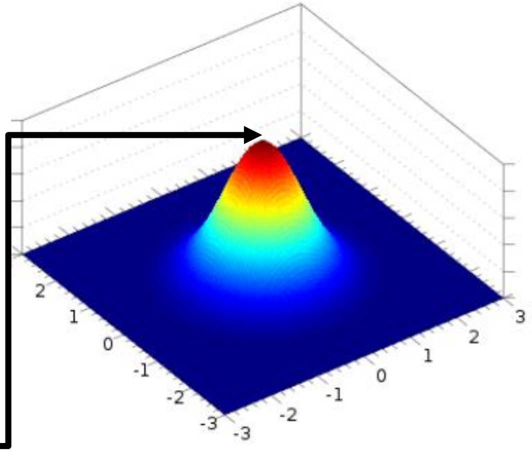


2D ELLIPTICAL GAUSSIAN INTERPOLATION

1. **Score maps** that **passed** the evaluation criteria
2. The **peak** computed earlier is obtained
3. The **neighboring region** to the peak pixel is found
4. Least squares adjustment to find the optimal 2D elliptical Gaussian **fit**
5. The **highest point** of the **fitted** Gaussian surface is the new **matching location** with **subpixel accuracy**

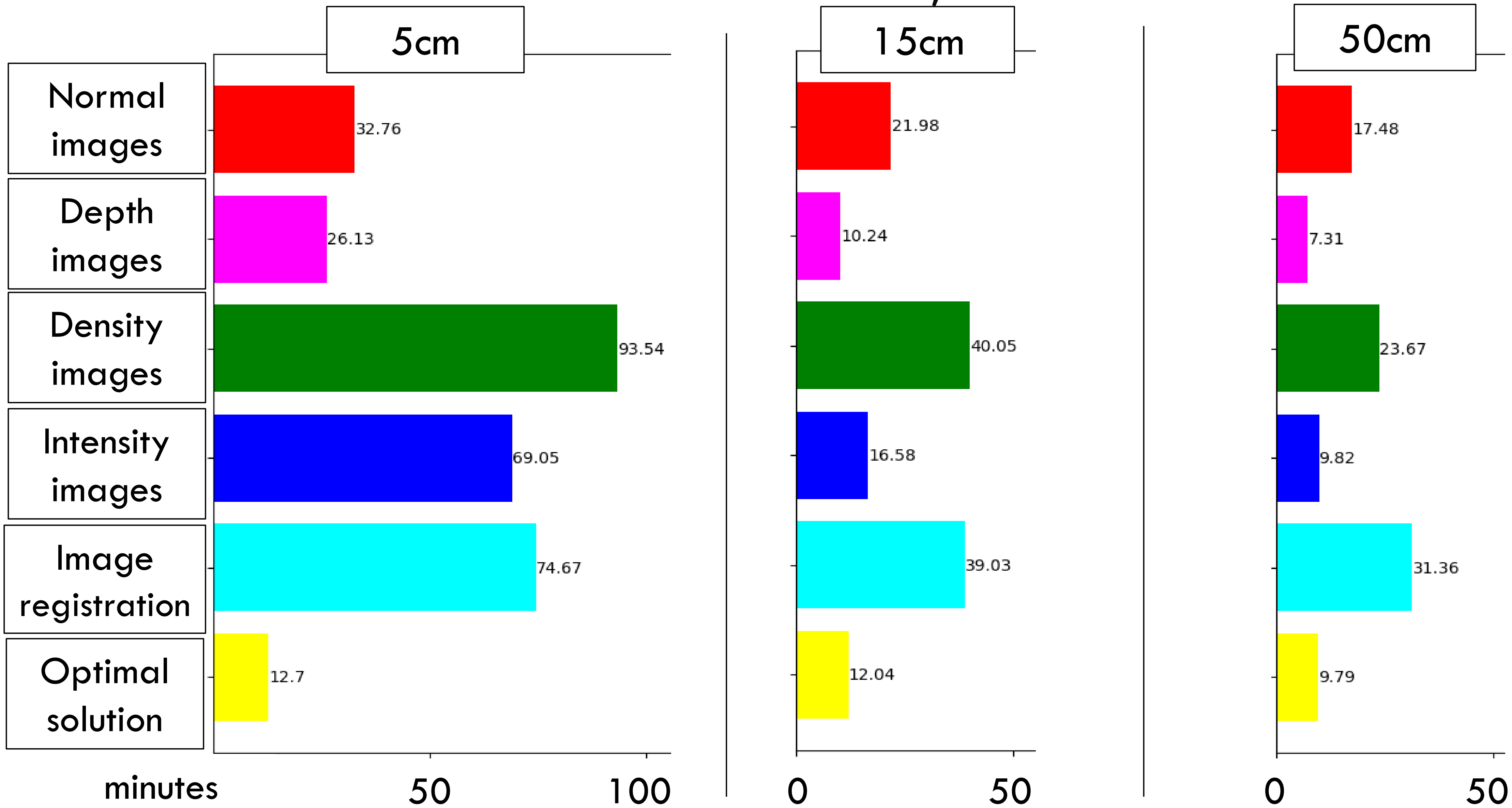
0	2362	7134	17489	28672	12523	5242	3195	2185
0	2521	5149	16805	30299	11648	4783	3780	2759
0	908	2956	17913	33446	15011	4952	3948	2903
0	593	5777	21010	37484	22585	9557	8919	8291
737	1470	7607	19113	65535	41452	12594	3818	2634
428	1392	2364	14868	36470	21889	2100	2223	1045
34	429	3847	13457	32818	22204	4622	2990	1891
0	0	3223	11988	33745	26056	6424	4960	3855
773	1002	4673	11008	34129	28899	8439	4935	2873





METHOD’S PERFORMANCE

EXECUTION TIMES: 5886 IMAGE PAIRS, 218 POINT CLOUD PAIRS



OVERALL QUALITY EVALUATION

Is a translation estimation **precisely measured?**

Precision

Standard deviation of accepted estimations

Is a translation estimation **strongly checked?**

Internal Reliability

Number of **accepted** images matchings

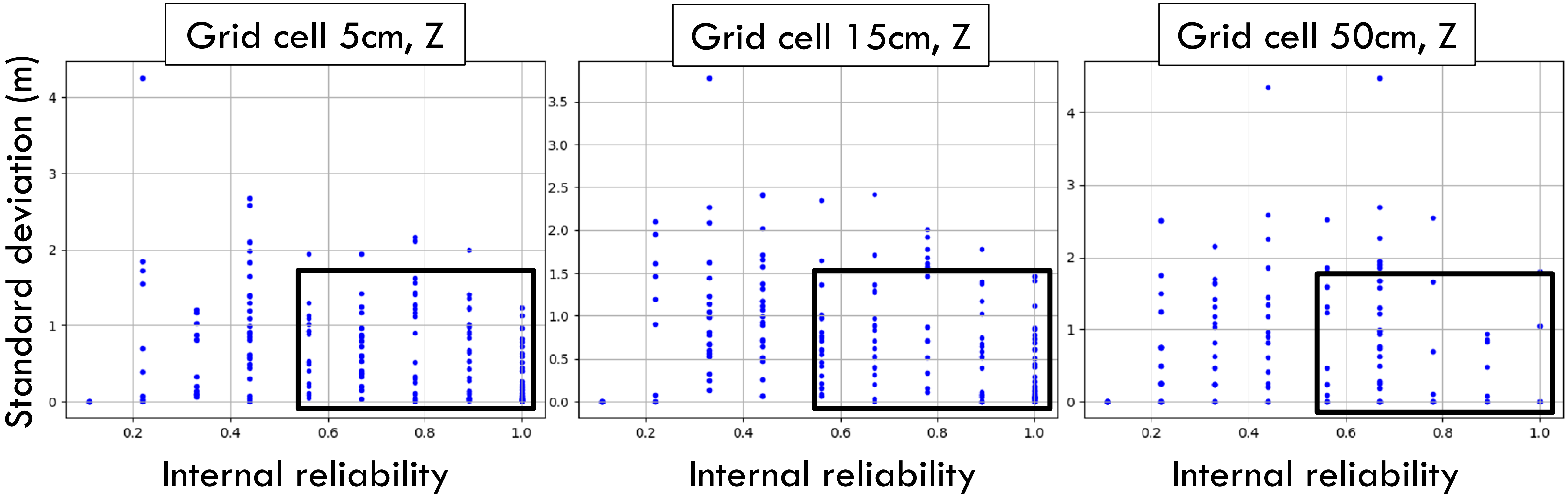
What is the **influence** from possible **undetected errors?**

External Reliability

Reliability **weights** based on possible **undetected errors**

INTERNAL RELIABILITY – PRECISION

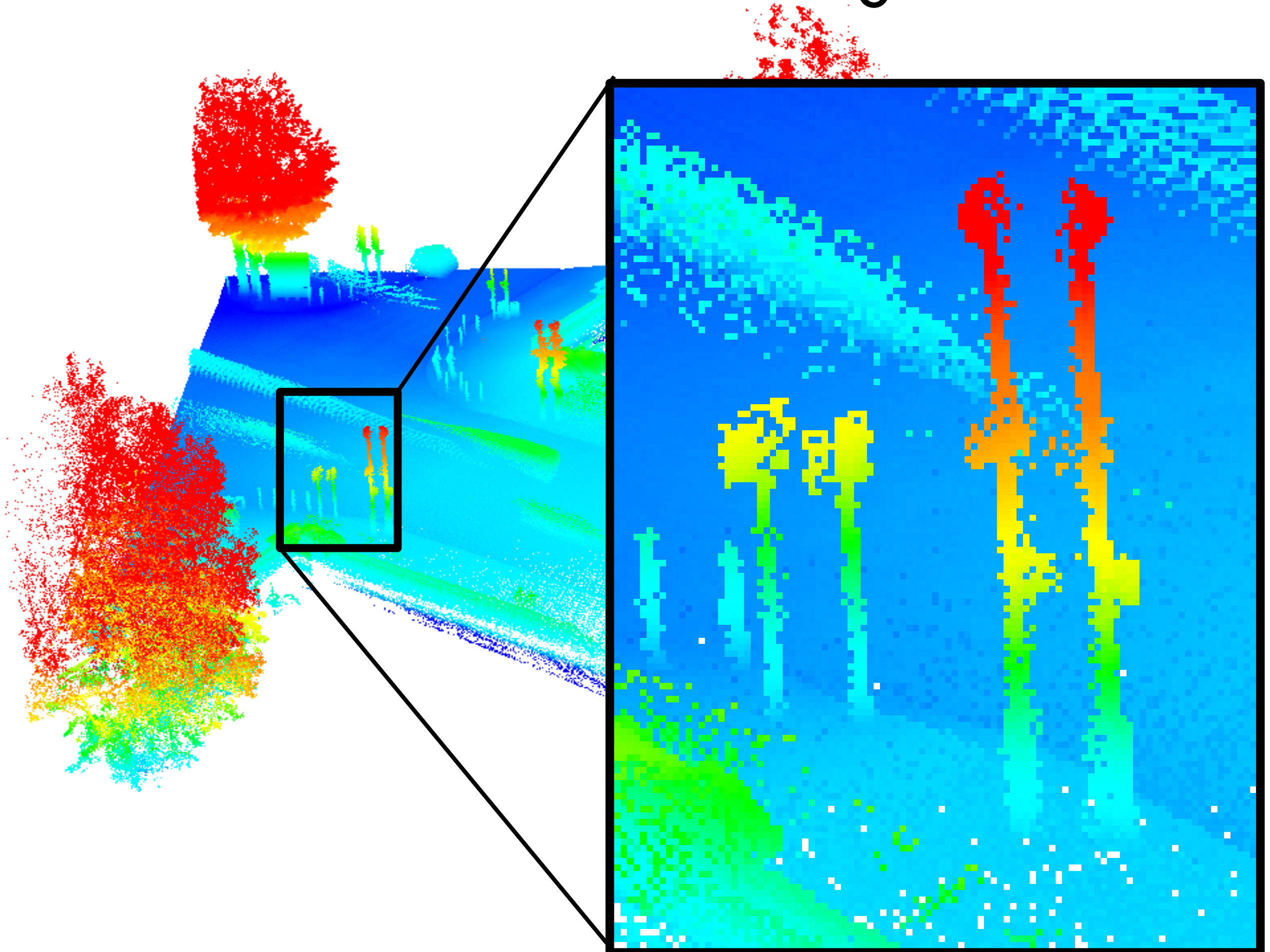
LOW Standard deviation (MIN = 0) **HIGH** Internal reliability (MAX = 1)



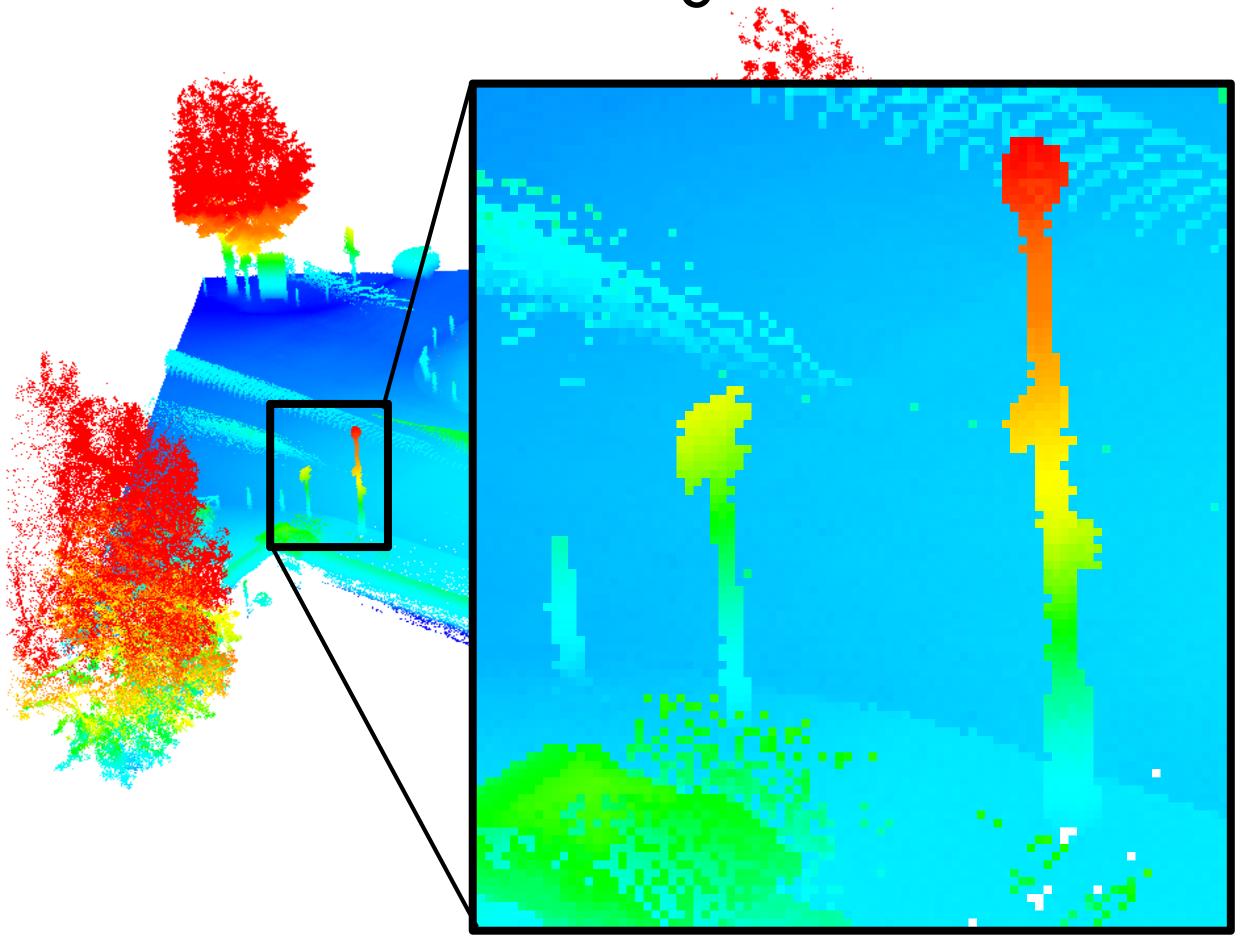
Number of **accepted** images matchings

CASE 1: BIG OVERLAP, CHANGES IN THE SCENE, DISTINCT CORRSPONDING OBJECTS

Before registration

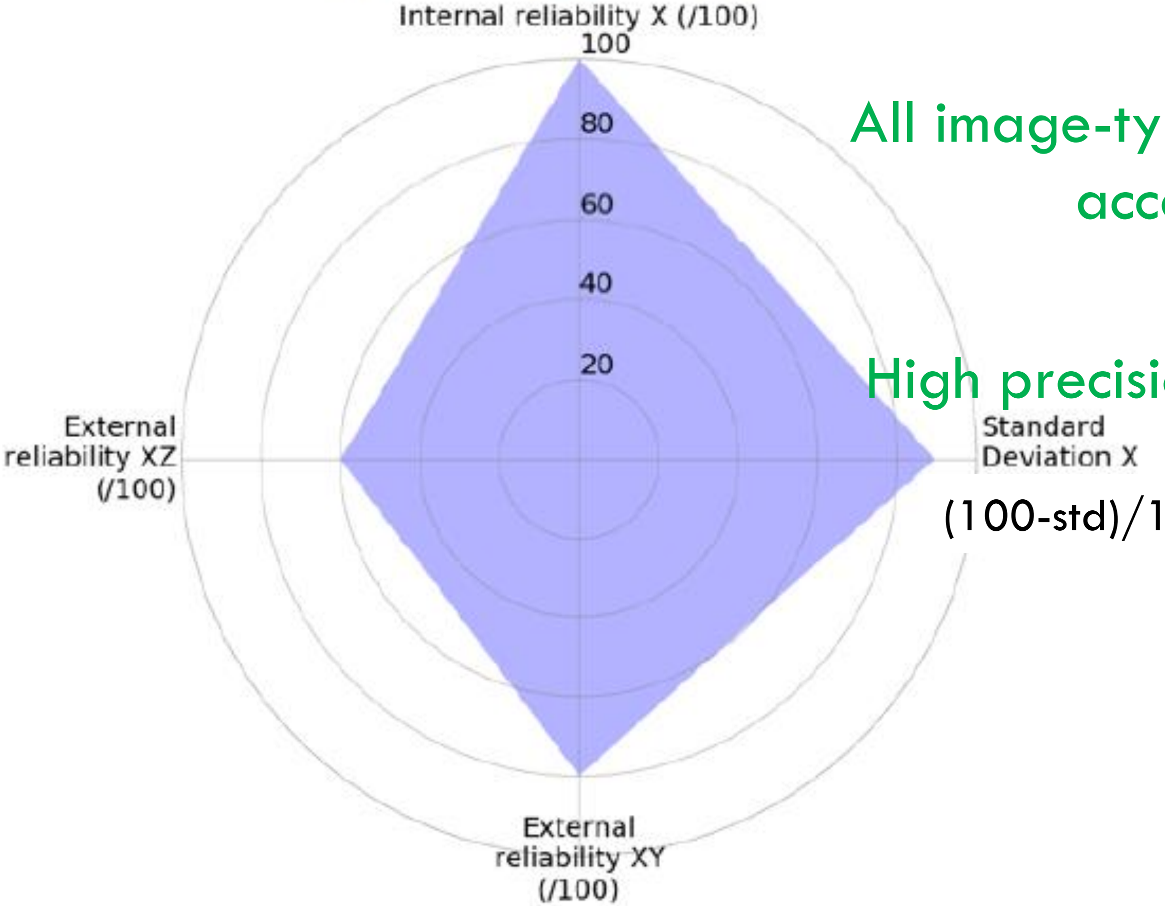


After registration

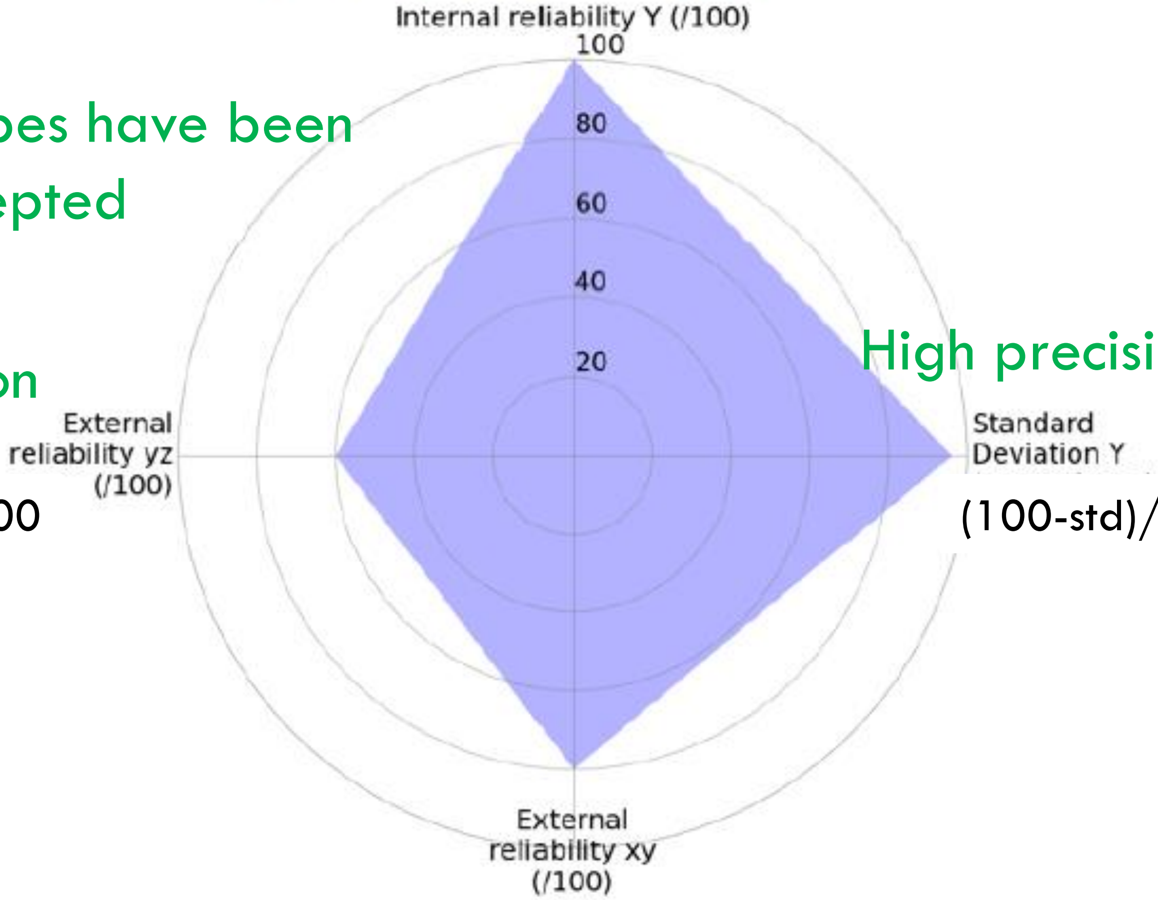


CASE 1: BIG OVERLAP, CHANGES IN THE SCENE, DISTINCT CORRSPONDING OBJECTS

X translation = -0.67m



Y translation = -0.03m



All image-types have been accepted

High precision

(100-std)/100

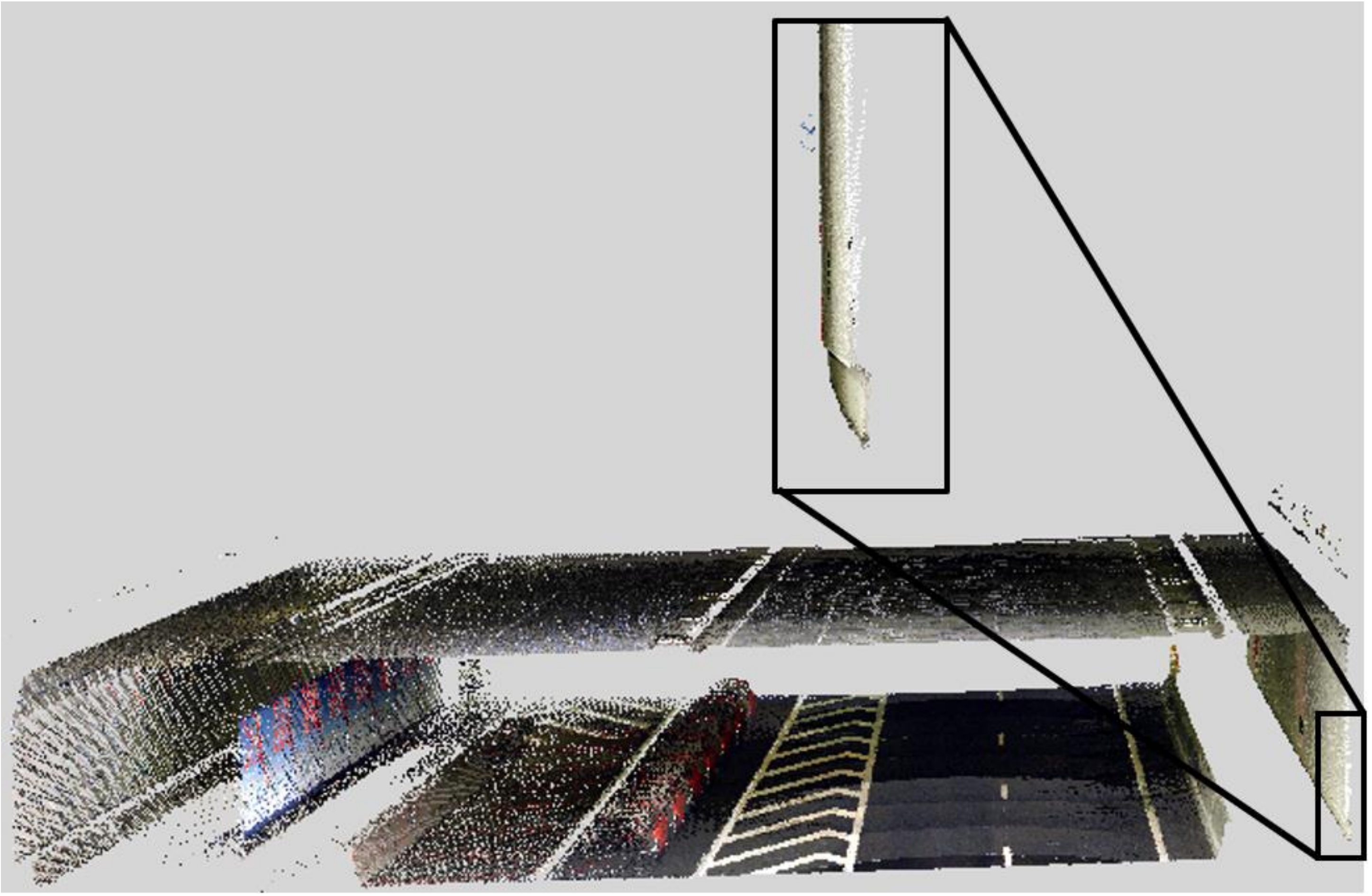
High precision

(100-std)/100

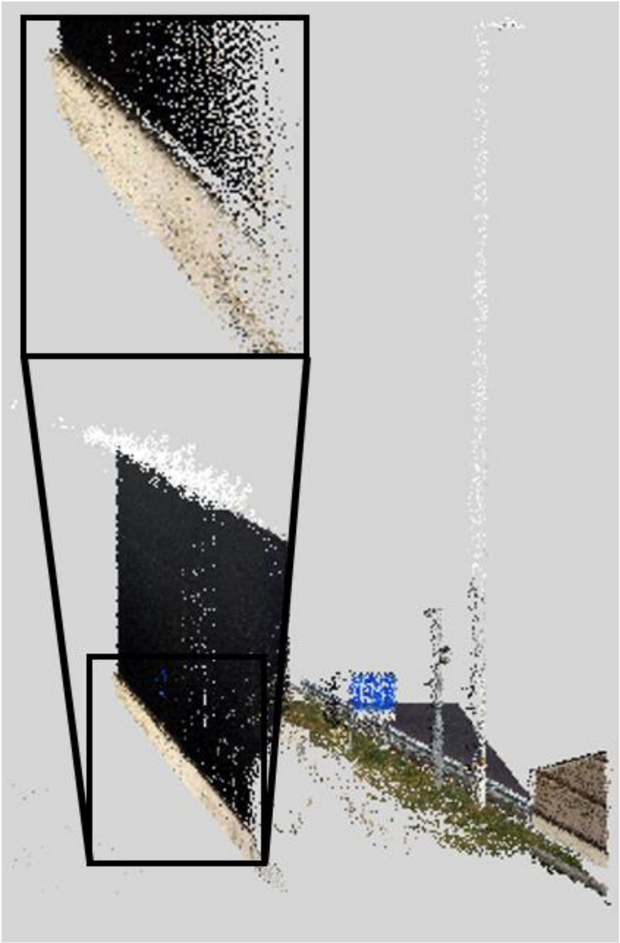
HIGH

CASE 2: ABSENCE OF OVERLAP, TUNNEL

Point cloud 1

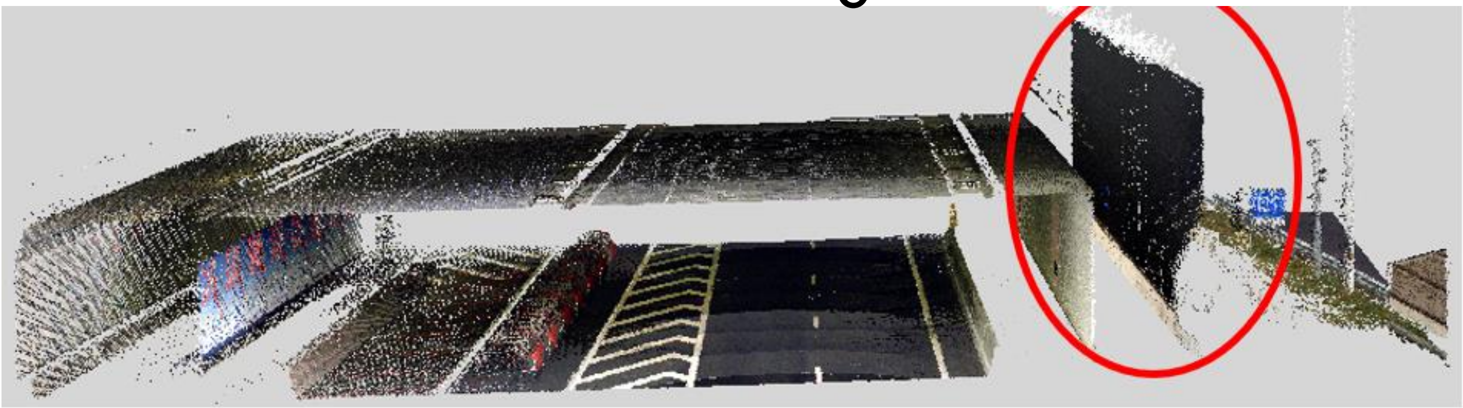


Point cloud 2

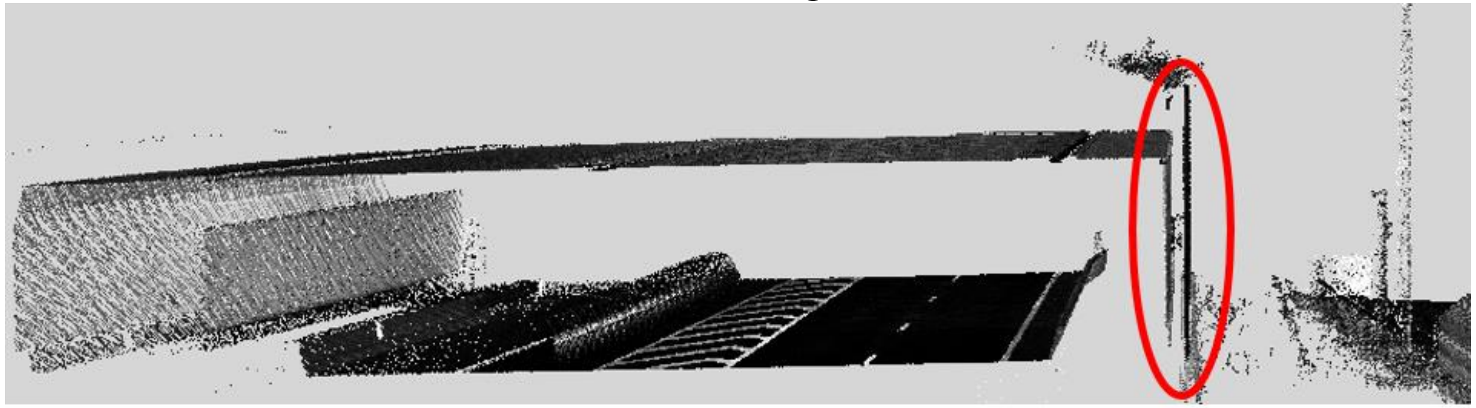


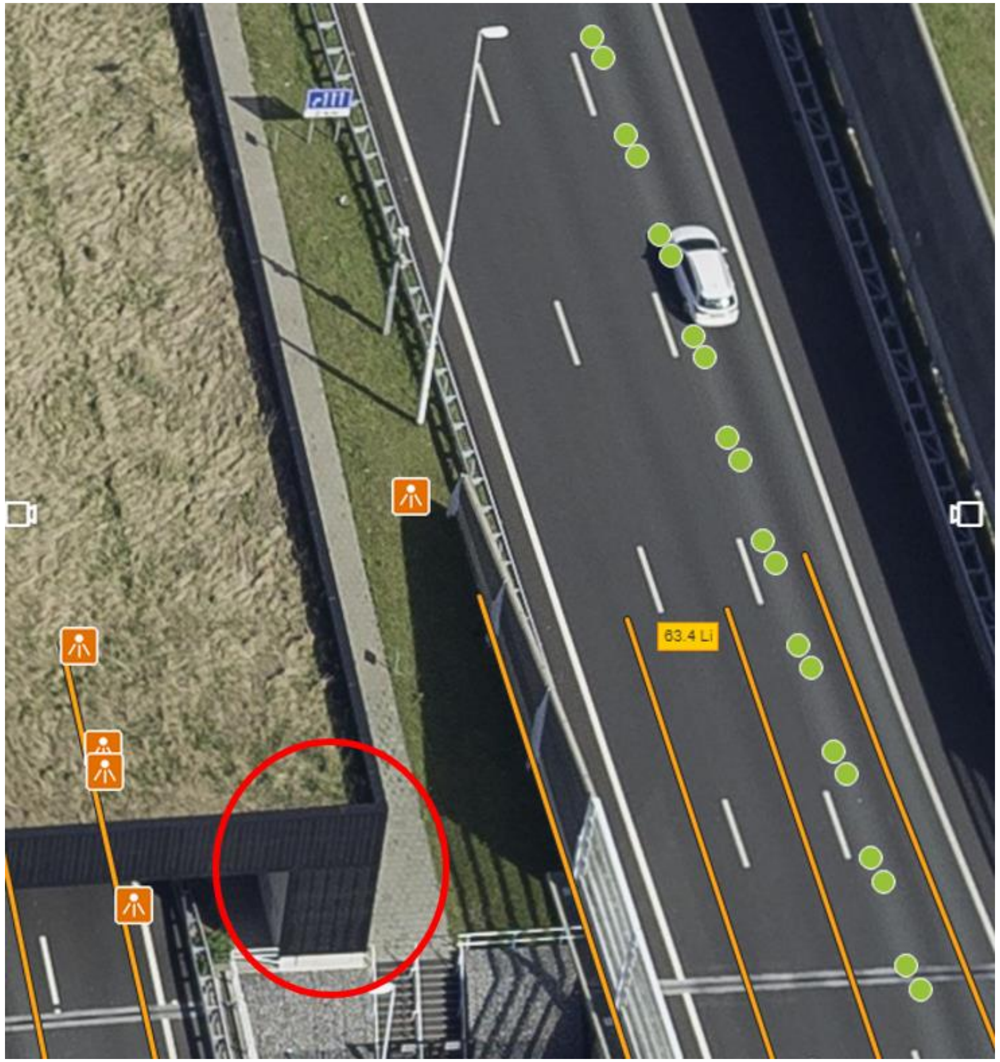
CASE 2: ABSENCE OF OVERLAP, TUNNEL

Before registration

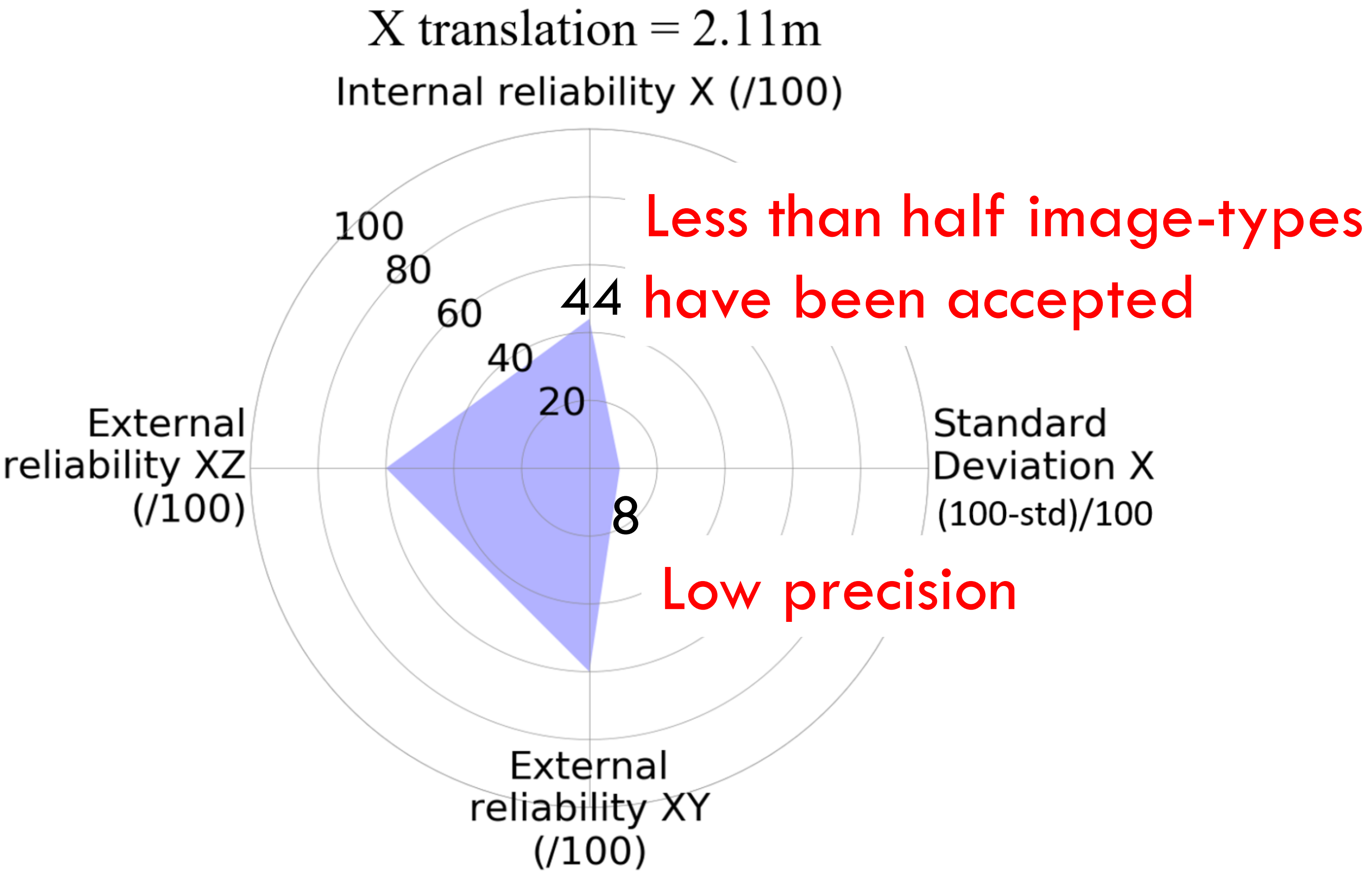


After registration



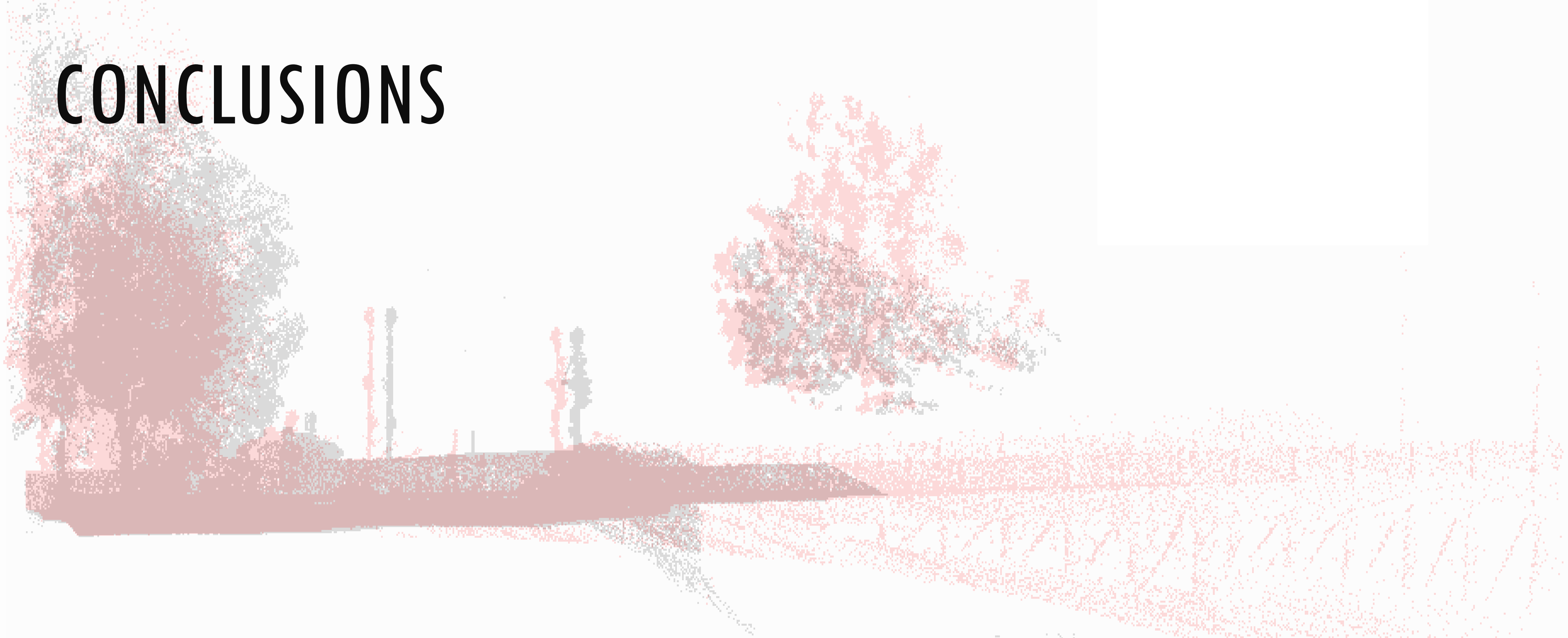


CASE 2: ABSENCE OF OVERLAP, TUNNEL



IDEAL RESULT

CONCLUSIONS



TO WHAT EXTENT IS IT POSSIBLE TO AUTOMATICALLY,
RELIABLY,
PRECISELY
AND EFFICIENTLY

ALIGN MOBILE LASER SCANNING DATA
RELATIVELY
USING AN IMAGE-BASED TECHNIQUE?

CONCLUSIONS – MAIN METHOD

1. It is possible to use an image-based technique to align mobile laser scanning data relatively.
2. More reliable and precise with small grid cells.
3. More efficient with large grid cells.
4. Even if good or poor quality the method informs the user. → Simple template matching technique → registration is more depended on number of pixels → possibility for redundant computations

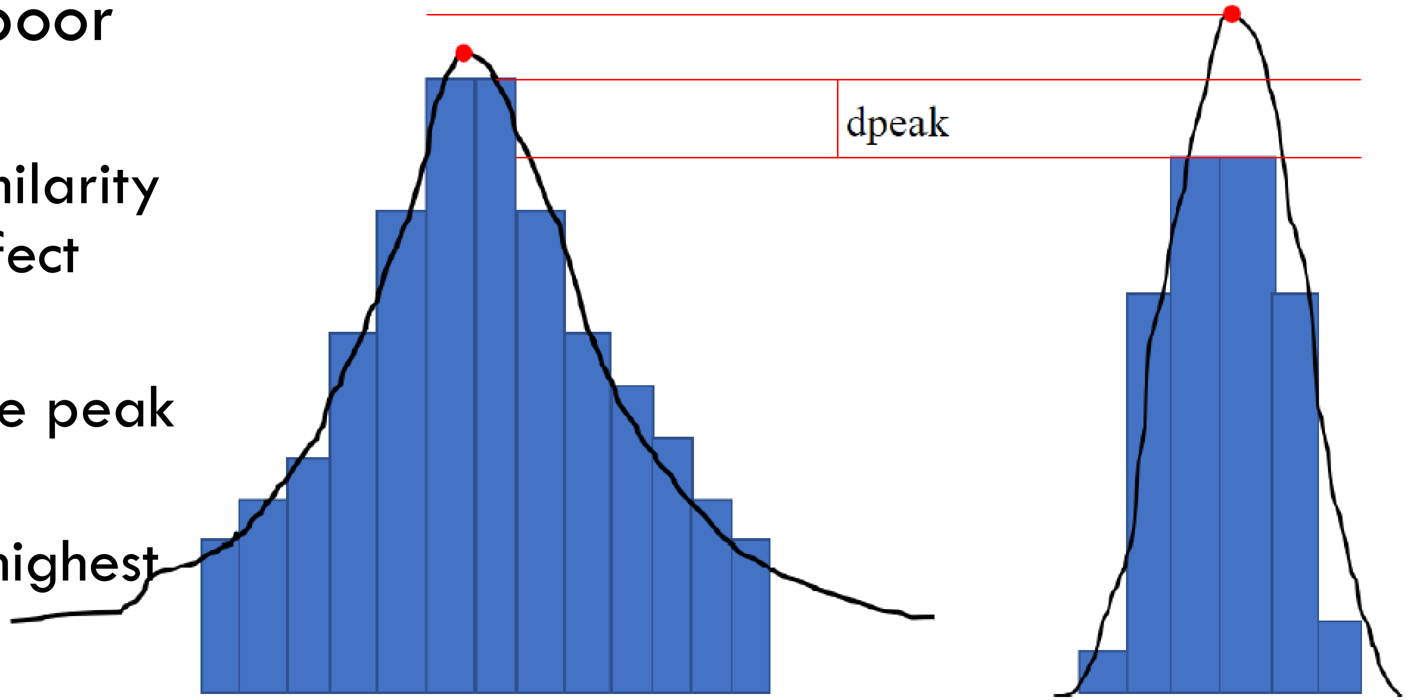
CONCLUSIONS – MAIN METHOD

It is possible to have good registration results:

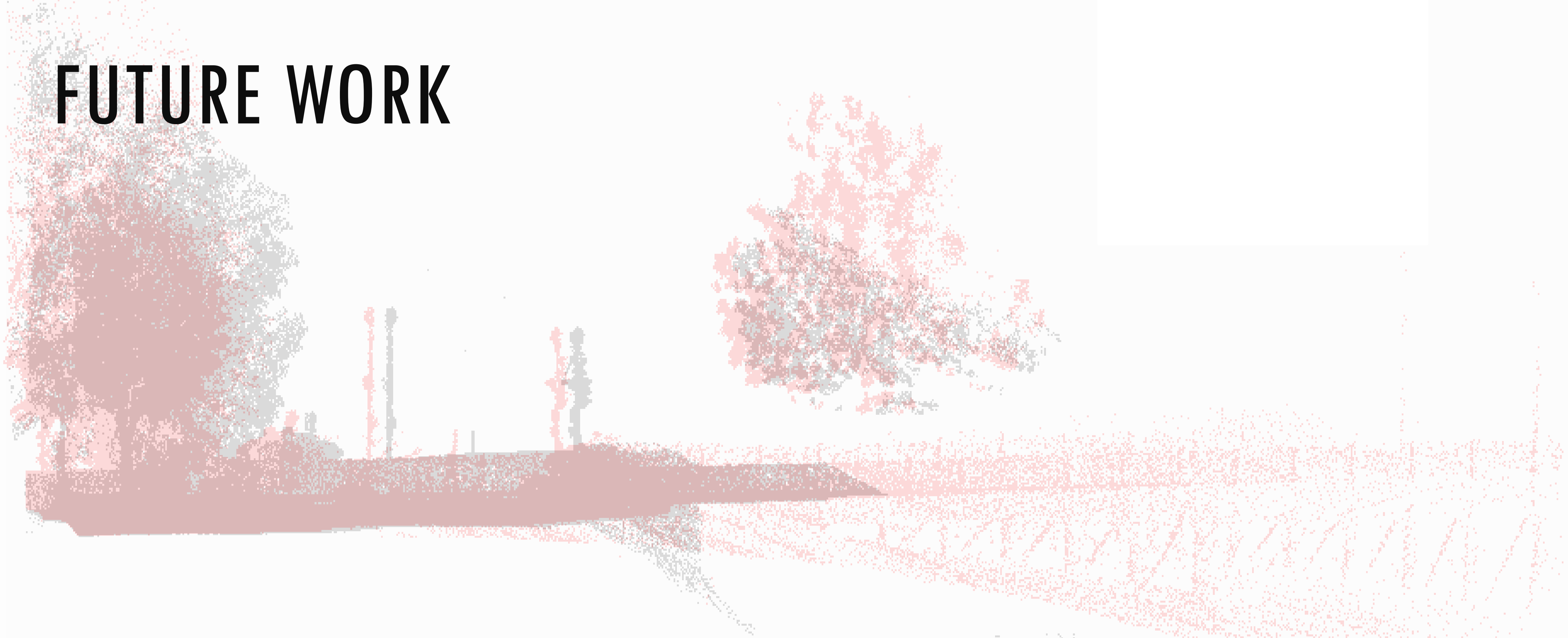
- When there is some overlap between two point clouds AND,
- corresponding objects between the point clouds are distinct in pairs of 2D projections.
- Even when the offset is large

CONCLUSIONS – SUB-PIXEL ACCURACY

1. Shows potential
2. Needs improvement
3. Why there are results with poor quality:
   - Different distributions of the similarity values, not always and not perfect Gaussian
   - Distribution of values around the peak not the same ($-\sigma x \neq +\sigma x$)
   - Sub-pixel applied <u>only</u> on the highest pixel



FUTURE WORK

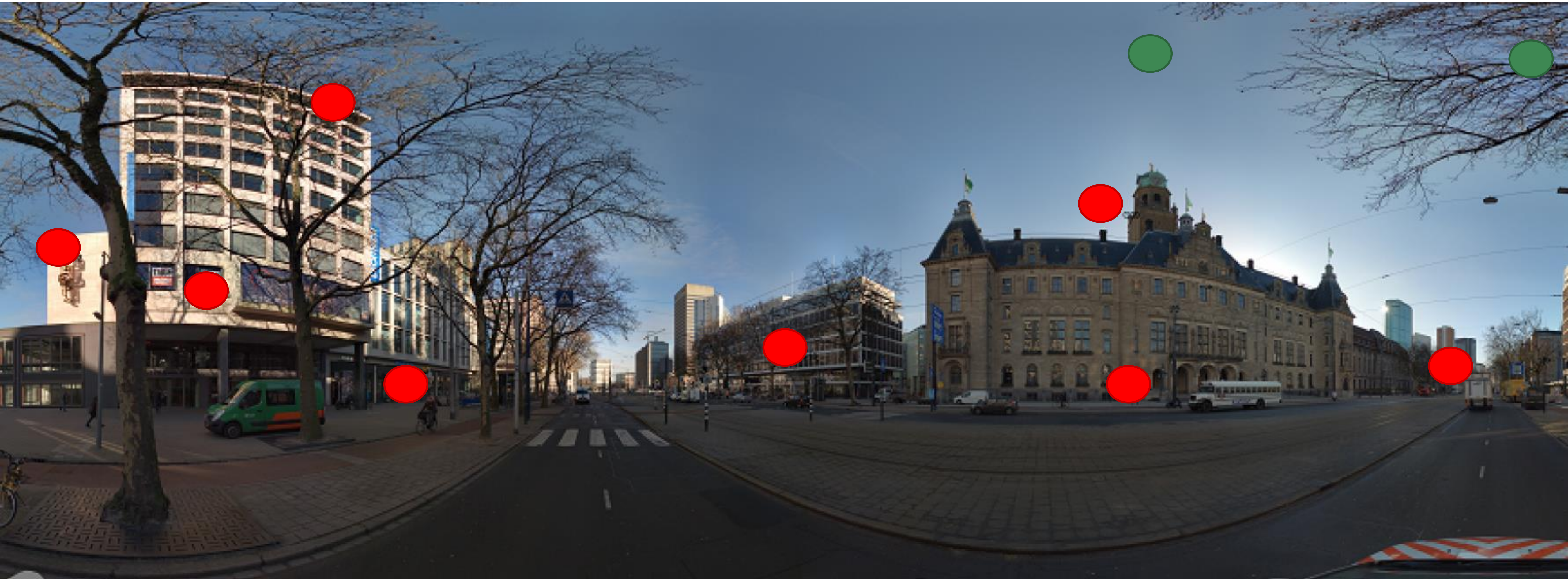


FUTURE WORK

1. Lidar compensation for vehicle distance
2. Improvement of sub-pixel accuracy method
3. Comparison with ICP

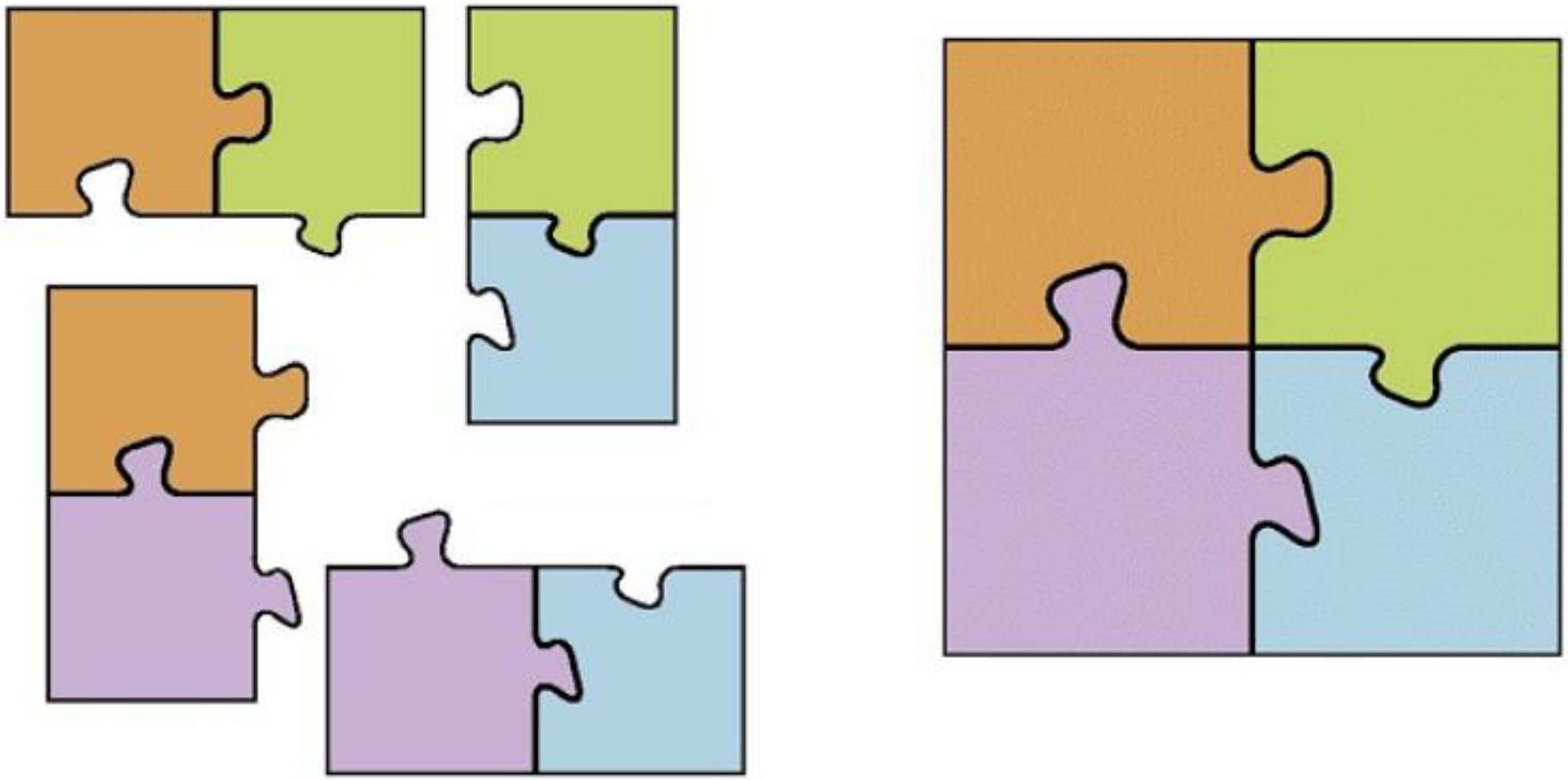
FUTURE WORK

- Reliability weights based on the accuracy of the point clouds absolute position



FUTURE WORK

- Global registration

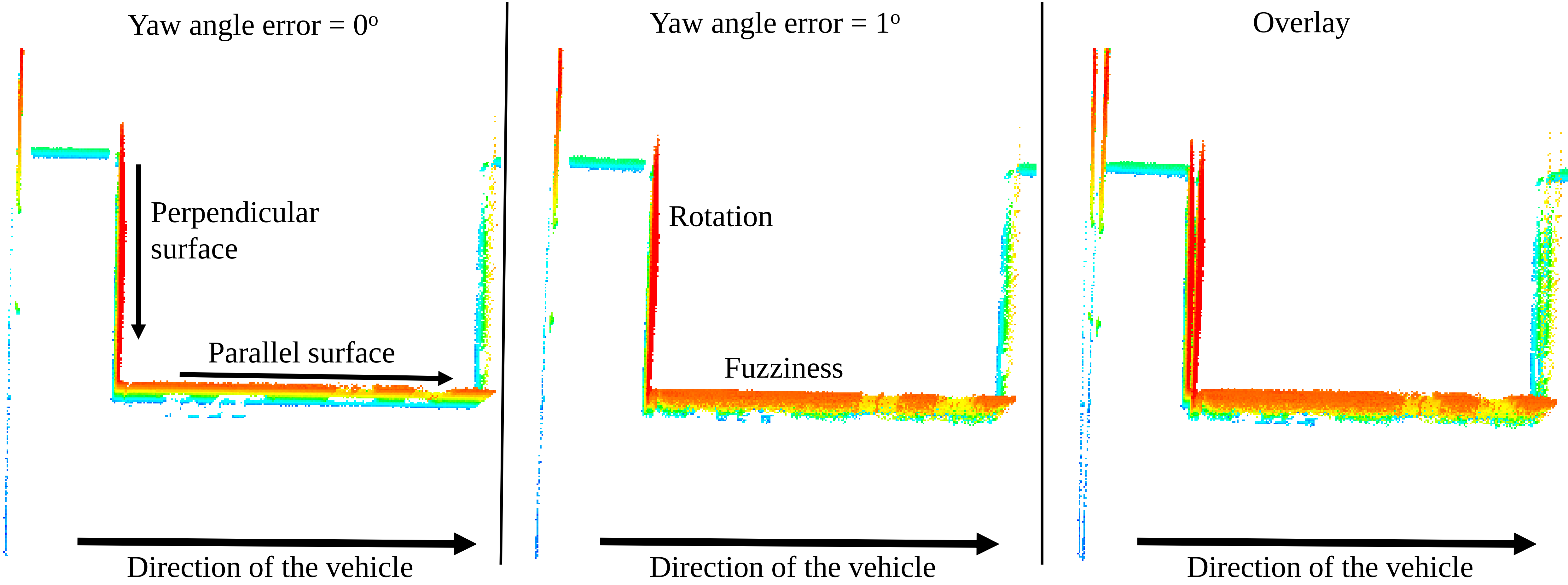


FUTURE WORK

- Moving objects rejection

FUTURE WORK

- Deal with the effects of orientation errors

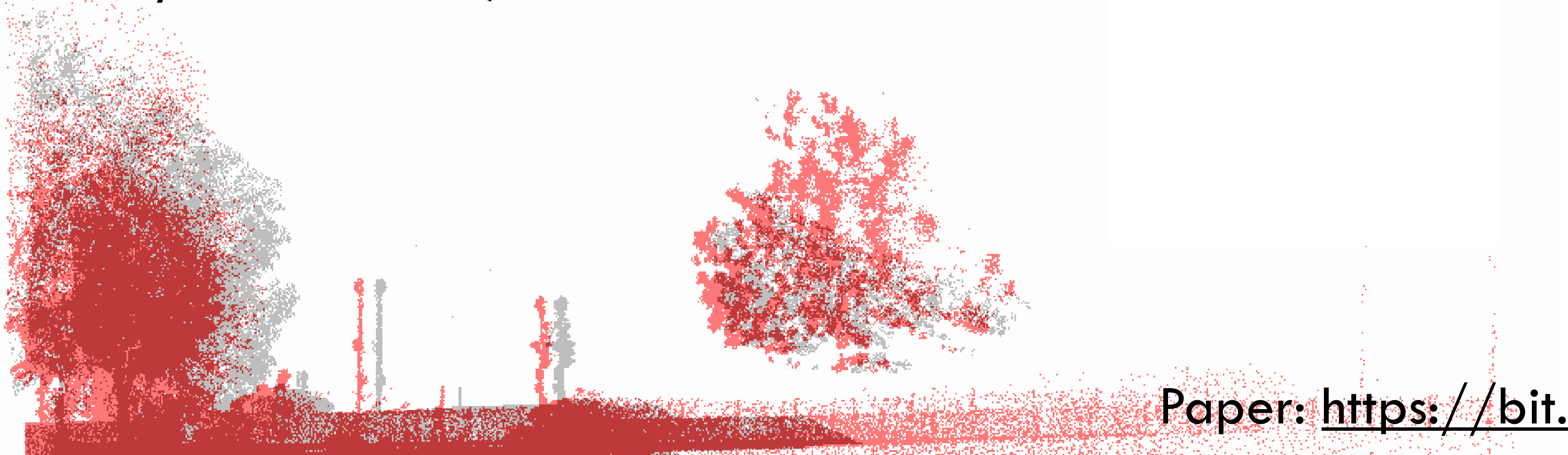


THANK YOU!
QUESTIONS?

Image-based method for the pairwise registration of mobile laser scanning point clouds

Antria Christodoulou

Supervisors: Peter van Oosterom, Peter Joosten, Berry van Someren, Ravi Y. Peters



Paper: https://bit.ly/2NIQuUx