Detecting Building Changes with a Certainty Index Using AHN and Rotterdam Point Cloud Dataset

Marieke van Arnhem | Master Thesis | P5

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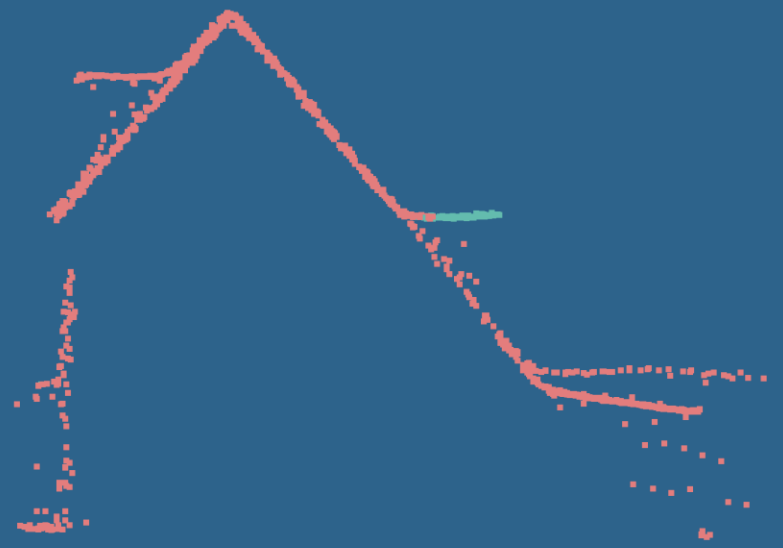
Ir. A. Verbraeck (Geodelta)

Co-Reader
Ir. D.C. Hulskemper

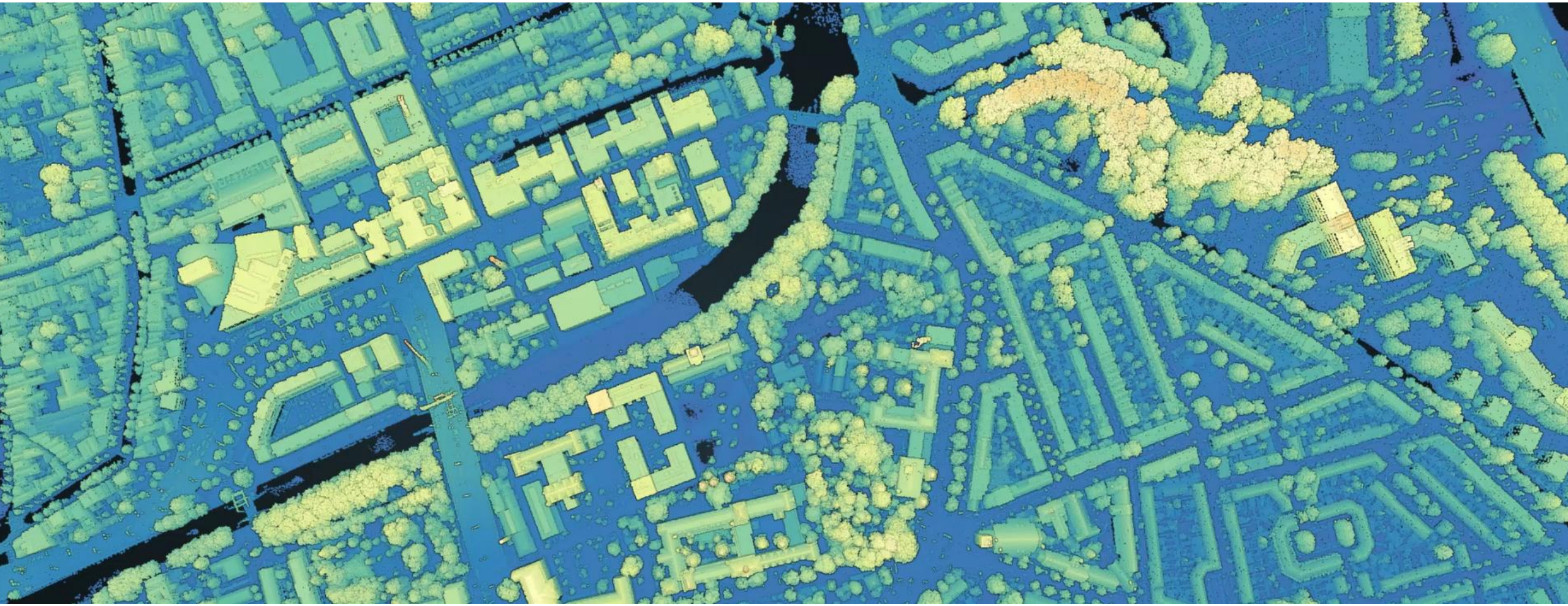


GEODELTA

TU Delft

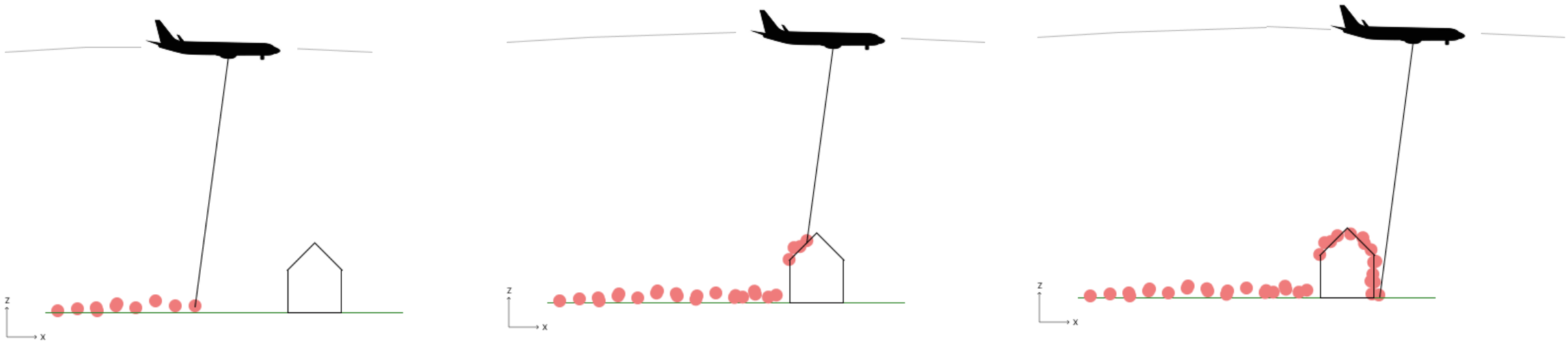
2D Data Not Always Sufficient

3D Data Essential



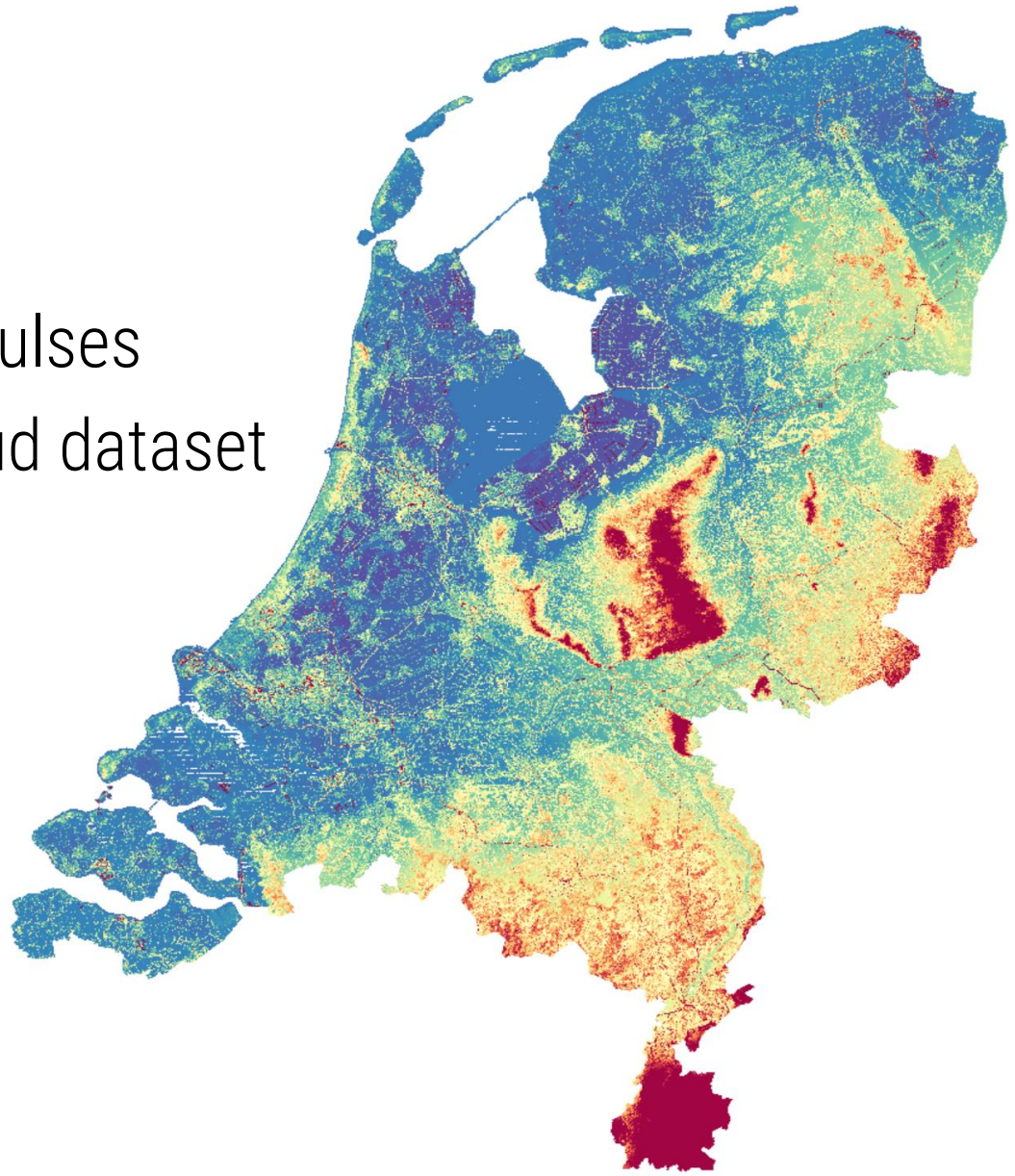
Point Clouds

- 3D Data
- LiDAR system: sending laser pulses

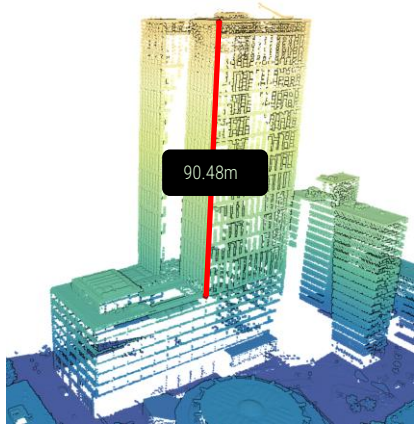


Point Clouds

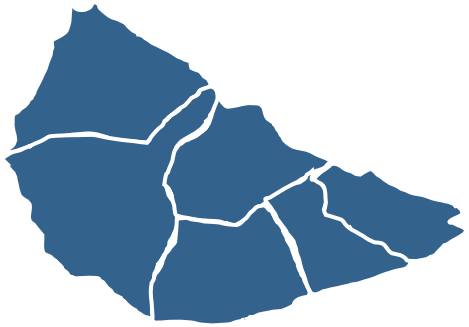
- 3D Data
- LiDAR system: sending laser pulses
- AHN: Dutch national point cloud dataset



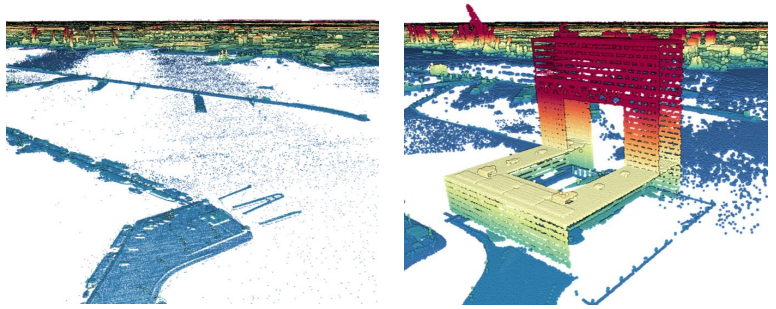
Point Clouds



Measuring and analysis



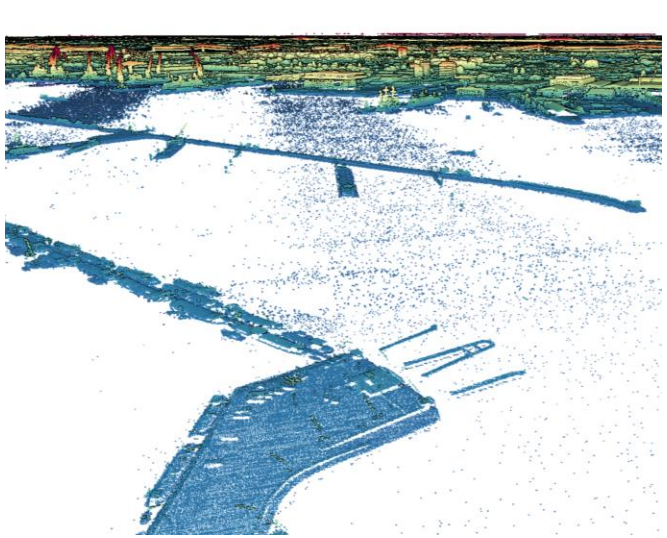
Managing urban spaces

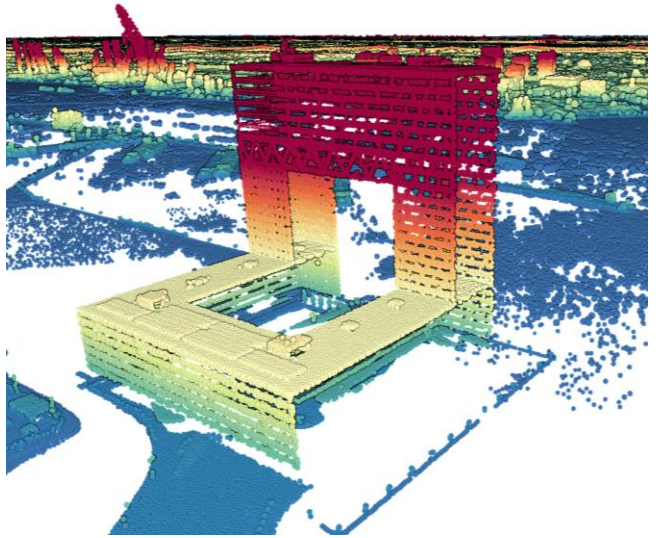


Change Detection

Building Change Detection

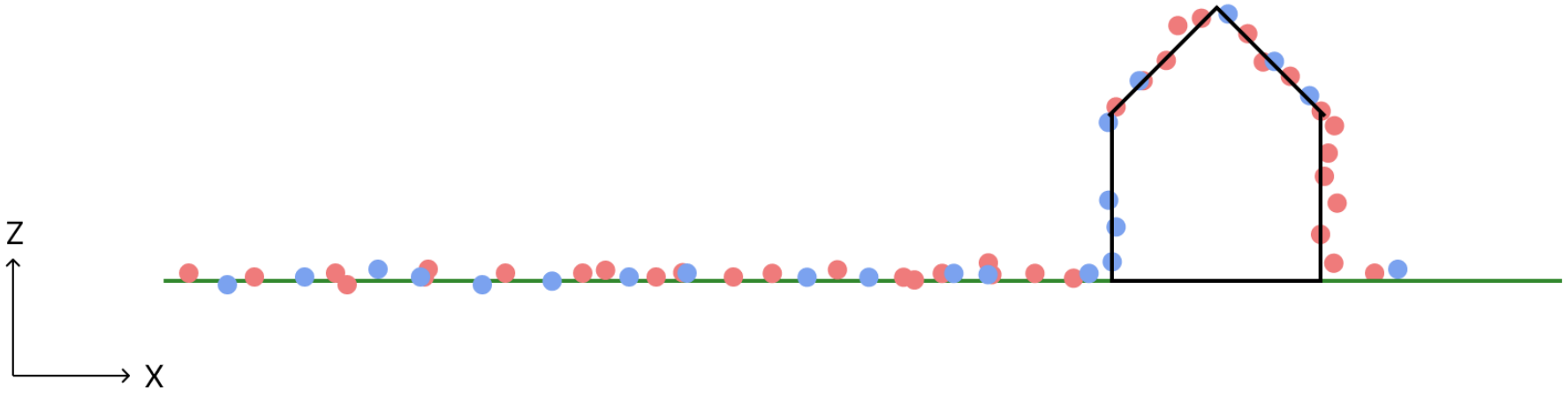
- Enable regular monitoring of urban development
- Support legal validation
- Facilitate the management of subsidy programs





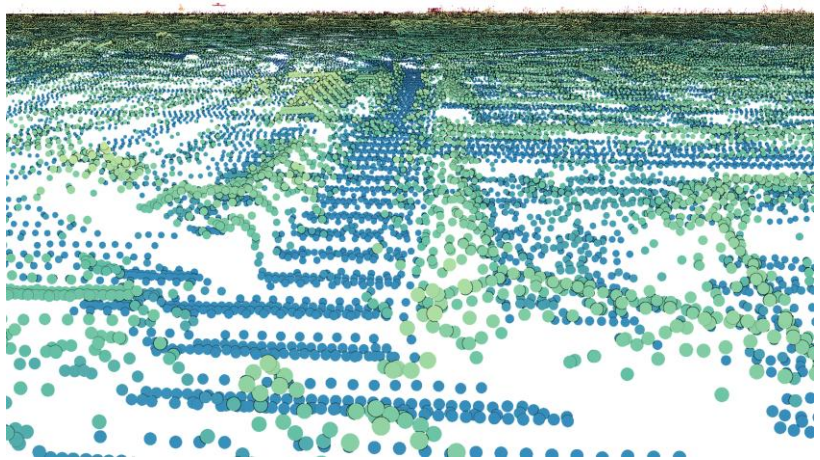
Limitations Point Cloud Change Detection

- No one-on-one match

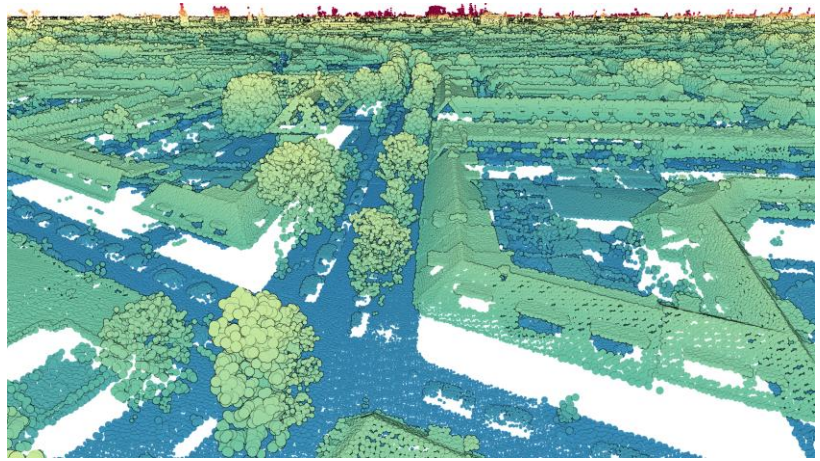


Limitations Point Cloud Change Detection

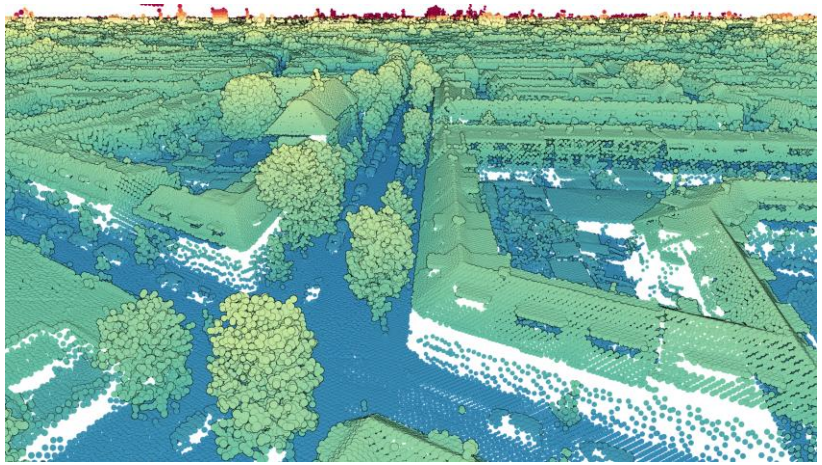
- No one-on-one match
- Density differences



AHN1



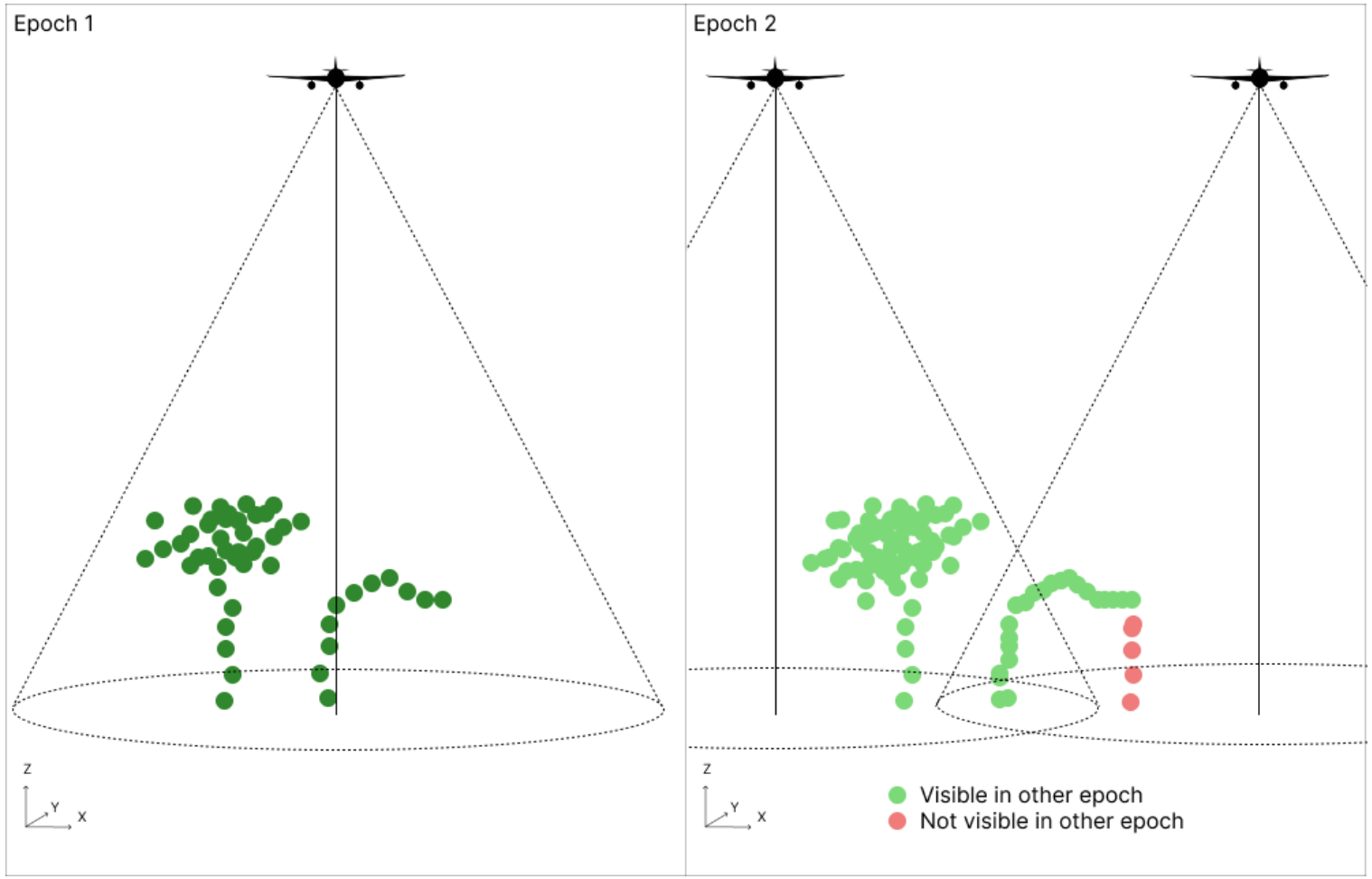
AHN4



AHN5

Limitations Point Cloud Change Detection

- No one-on-one match
- Density differences
- Occlusion



Limitations Point Cloud Change Detection

- No one-on-one match
- Density differences

→ Machine Learning algorithm
Synthetic dataset

- Occlusion

→ Certainty Index

To what extent can a building change detection method between two epochs of aligned point cloud datasets be developed to detect structural changes, maximizing reliability by using a certainty index?

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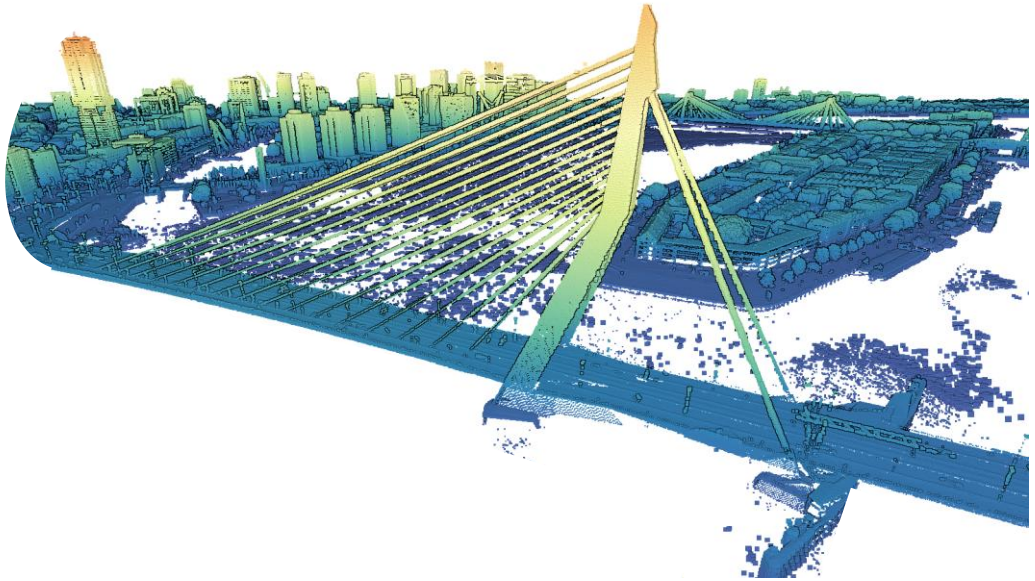
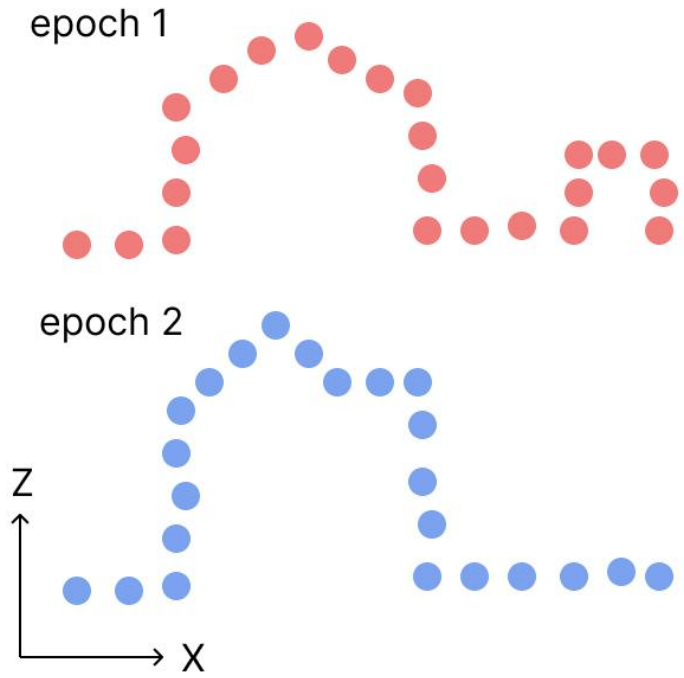
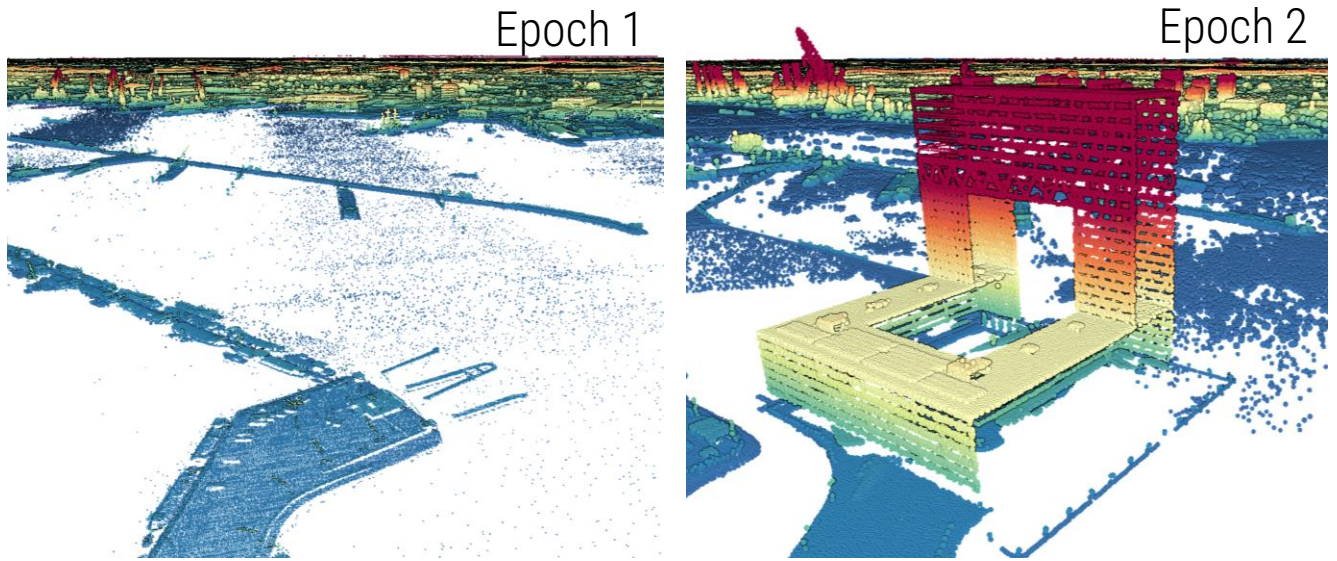


*To what extent can a building change detection method between two epochs of aligned **point cloud datasets** be developed to detect structural changes, maximizing reliability by using a certainty index?*



To what extent can a building change detection method between two ***epochs*** *of aligned* ***point cloud datasets*** *be developed to detect structural changes, maximizing reliability by using a certainty index?*



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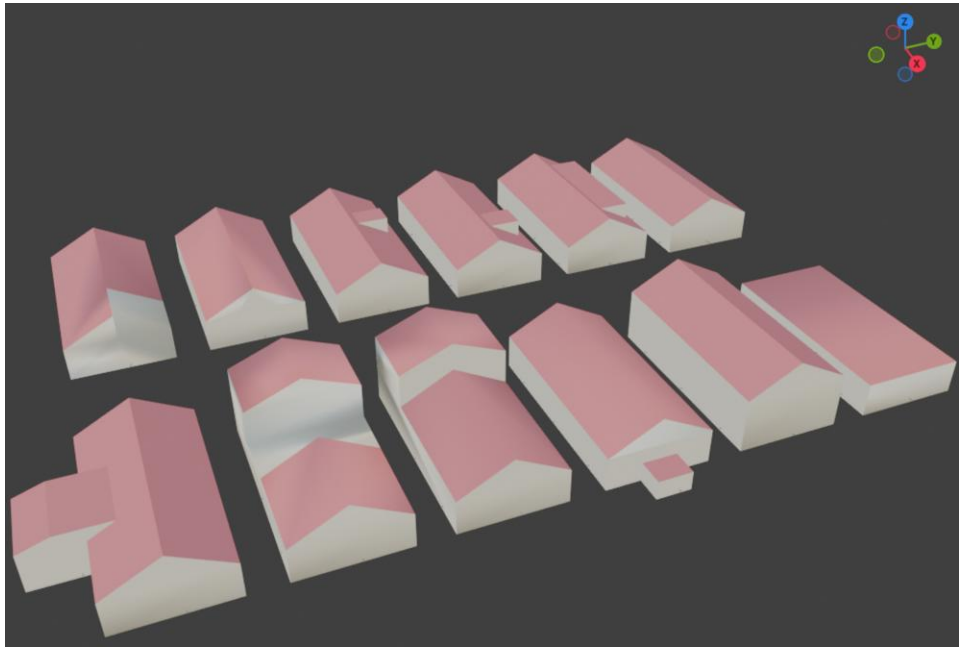
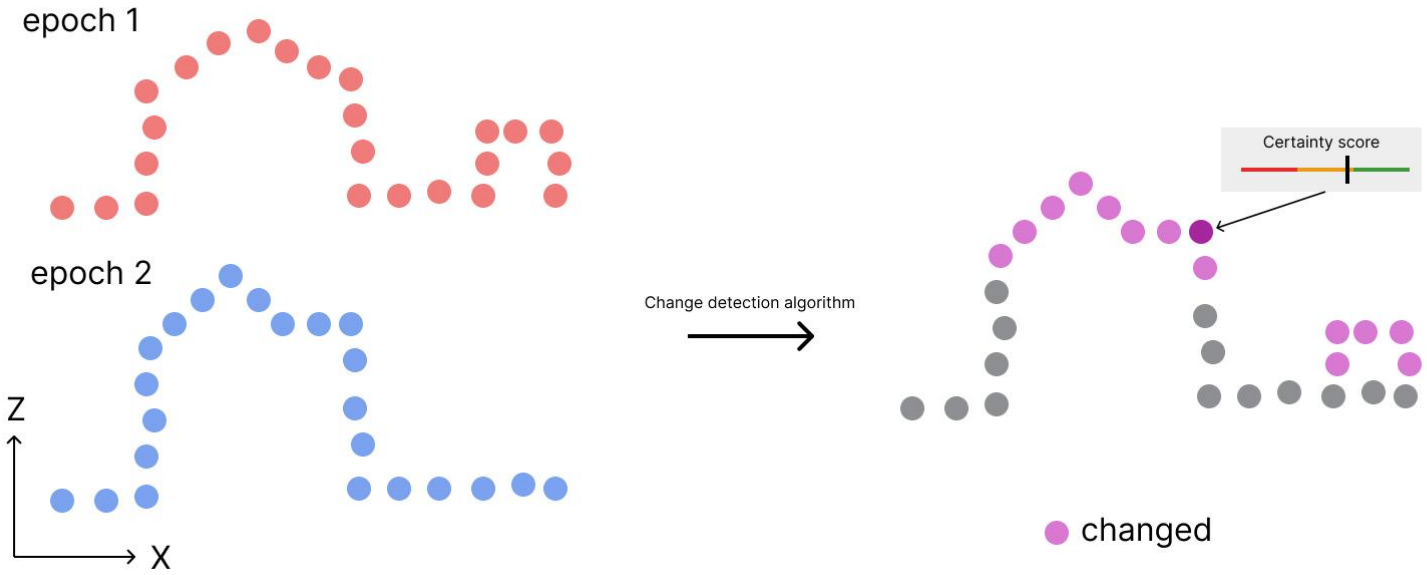
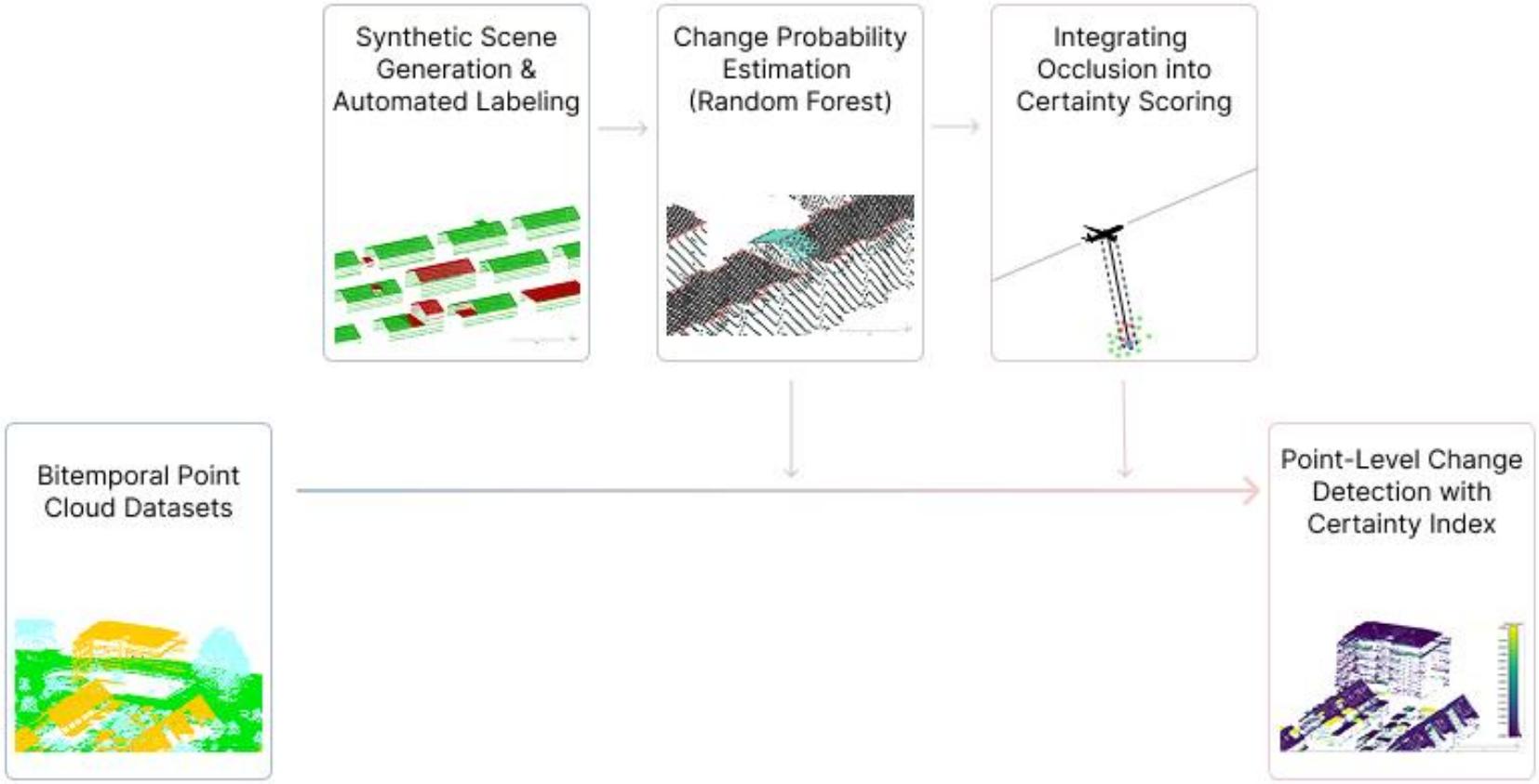


*To what extent can a **building change detection** method between two **epochs** of aligned **point cloud datasets** be developed to detect **structural changes**, maximizing reliability by using a certainty index?*



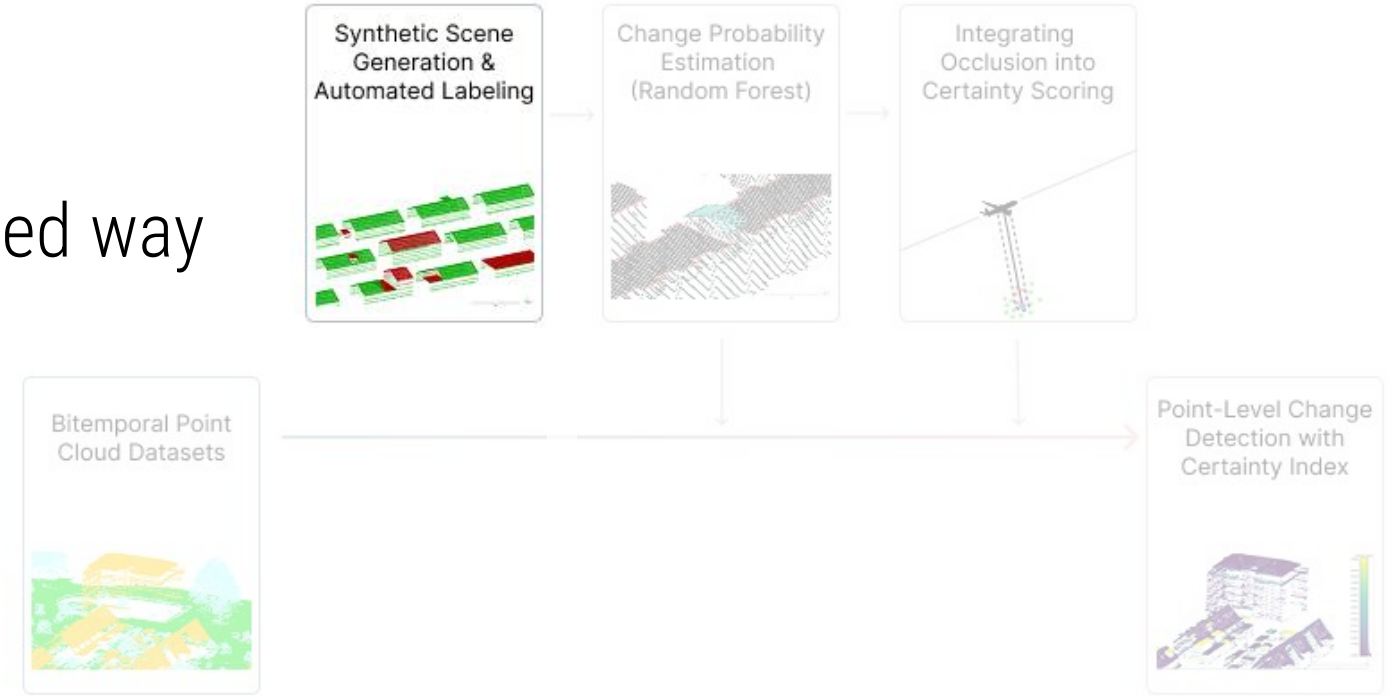
Overview


Synthetic Scene Generation & Automated Labeling
Change Probability Estimation (Random Forest)
Integrating Occlusion into Certainty Scoring
Bitemporal Point Cloud Datasets
Point-Level Change Detection with Certainty Index

Synthetic Scene

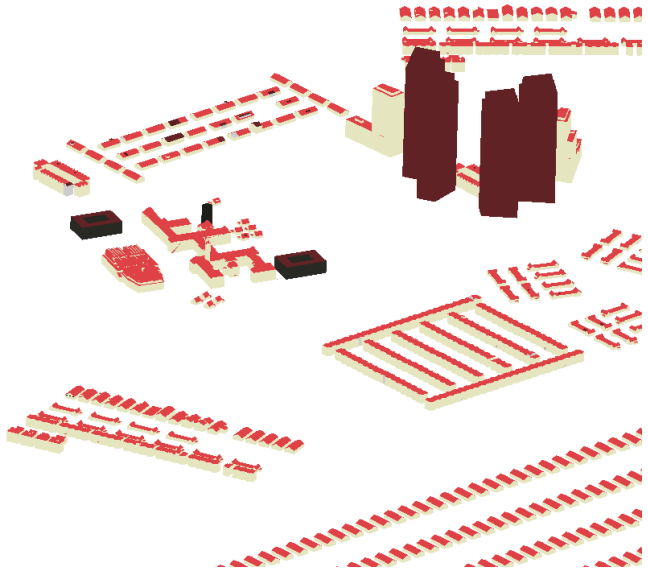
Motivation

- Training data
- Changes inserted in a controlled way
- Automatic labelling



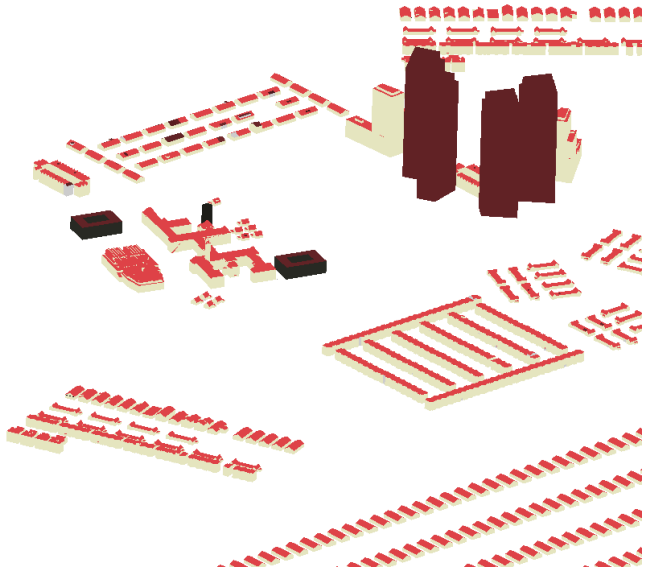
Synthetic Scene

1. Generate ground truth city scene

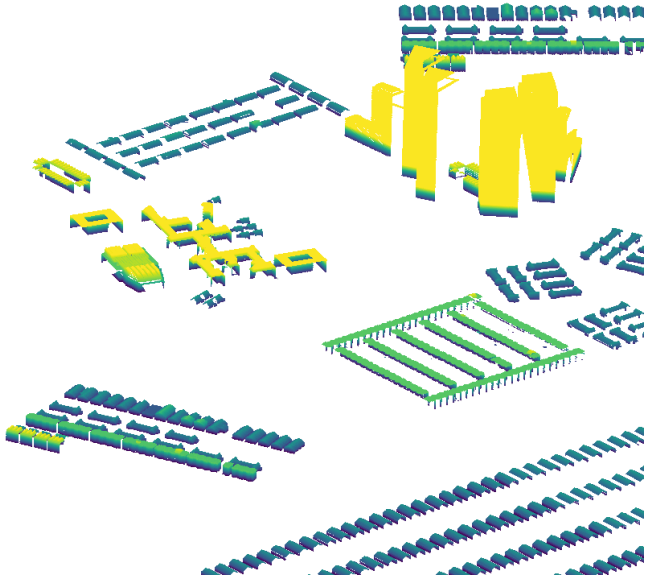


Synthetic Scene

1. Generate ground truth city scene

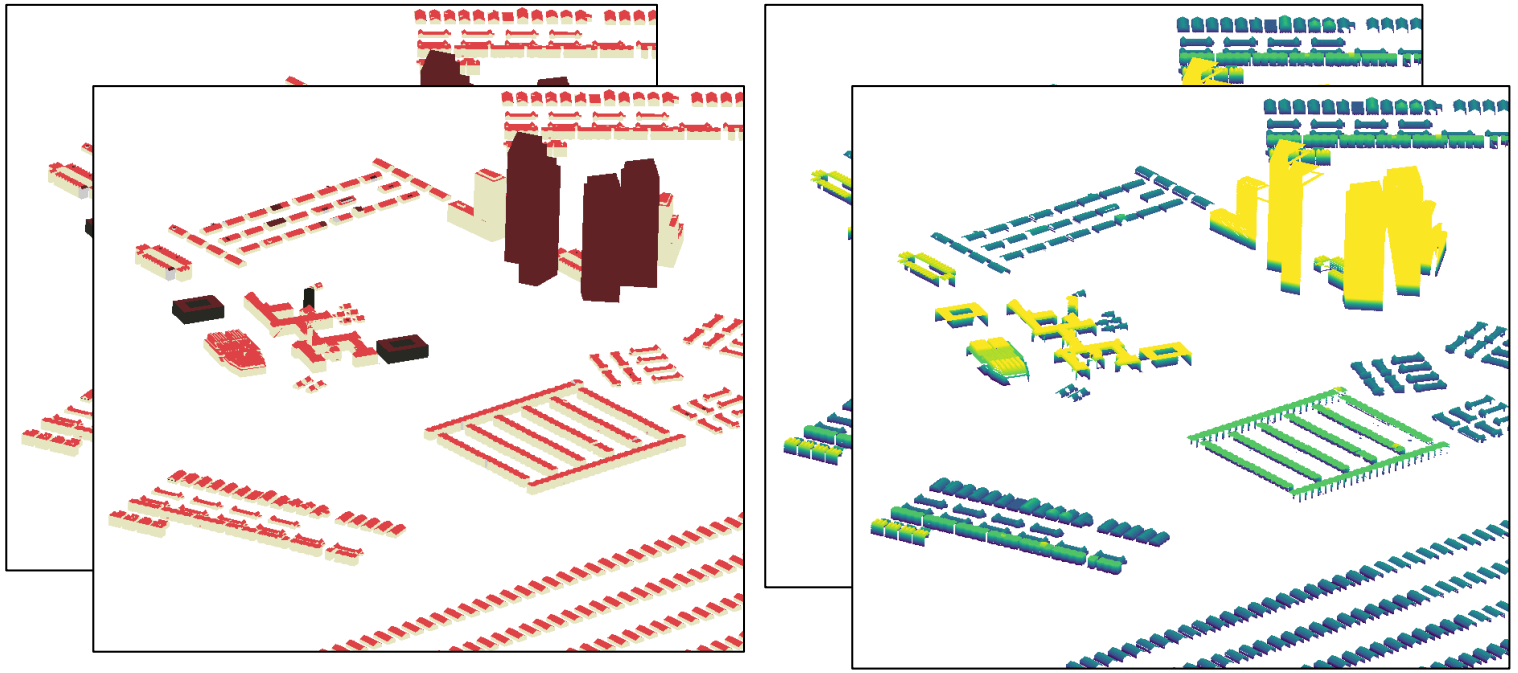


2. Generate point clouds from city scenes



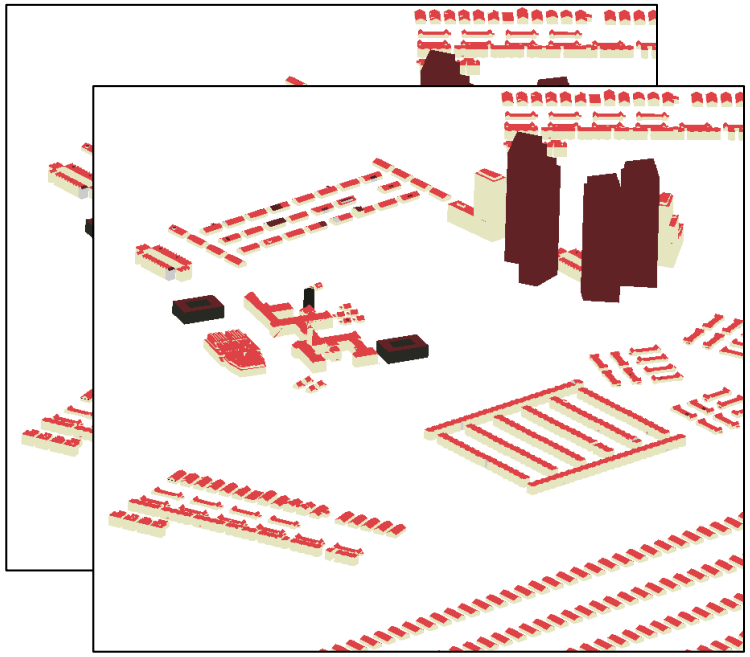
Synthetic Scene

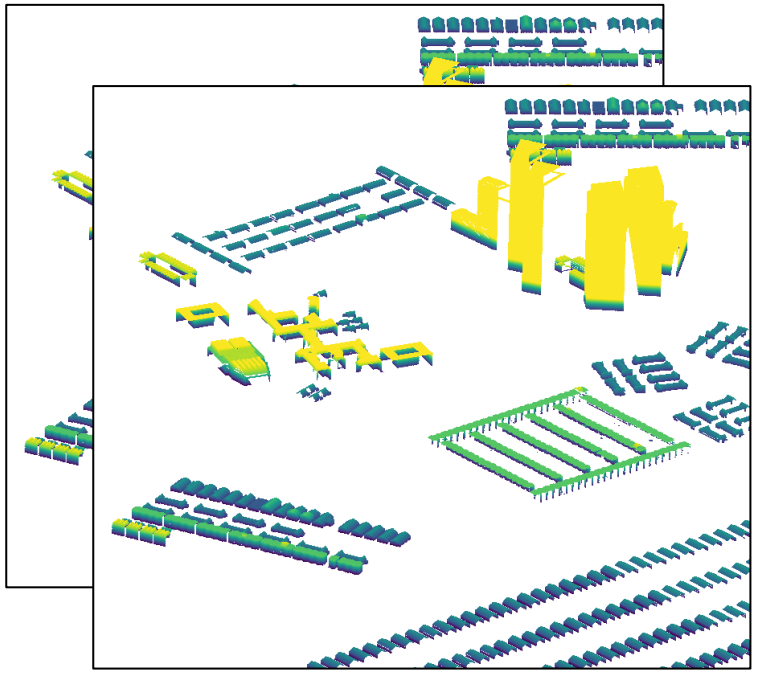
1. Generate ground truth city scene
2. Generate point clouds from city scenes

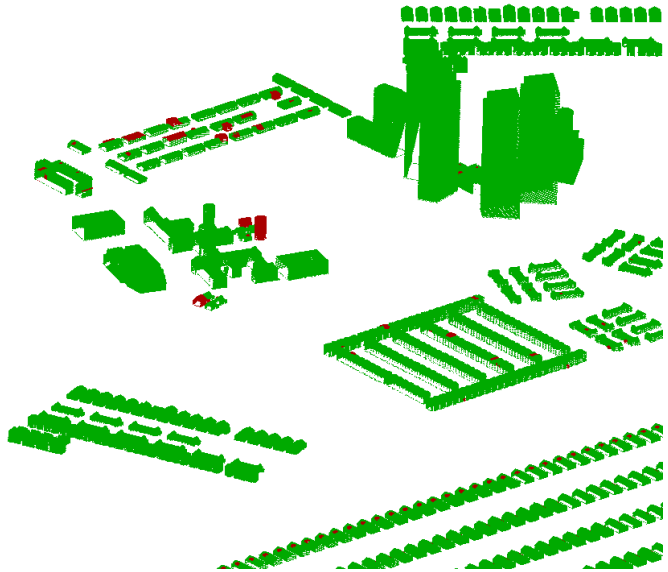


Synthetic Scene

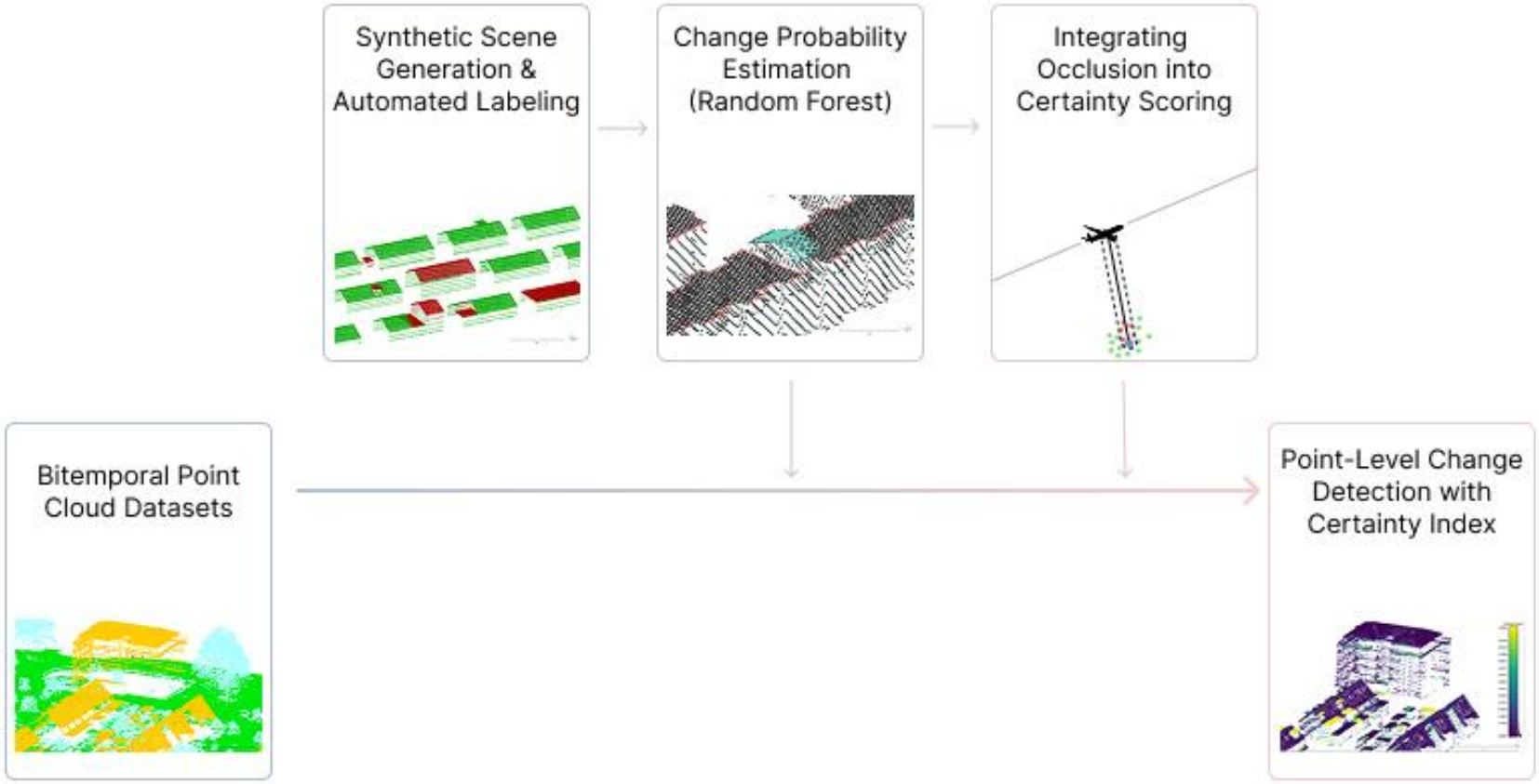
1. Generate ground truth city scene
2. Generate point clouds from city scenes
3. Automatic labelling changes







Overview


Synthetic Scene Generation & Automated Labeling
Change Probability Estimation (Random Forest)
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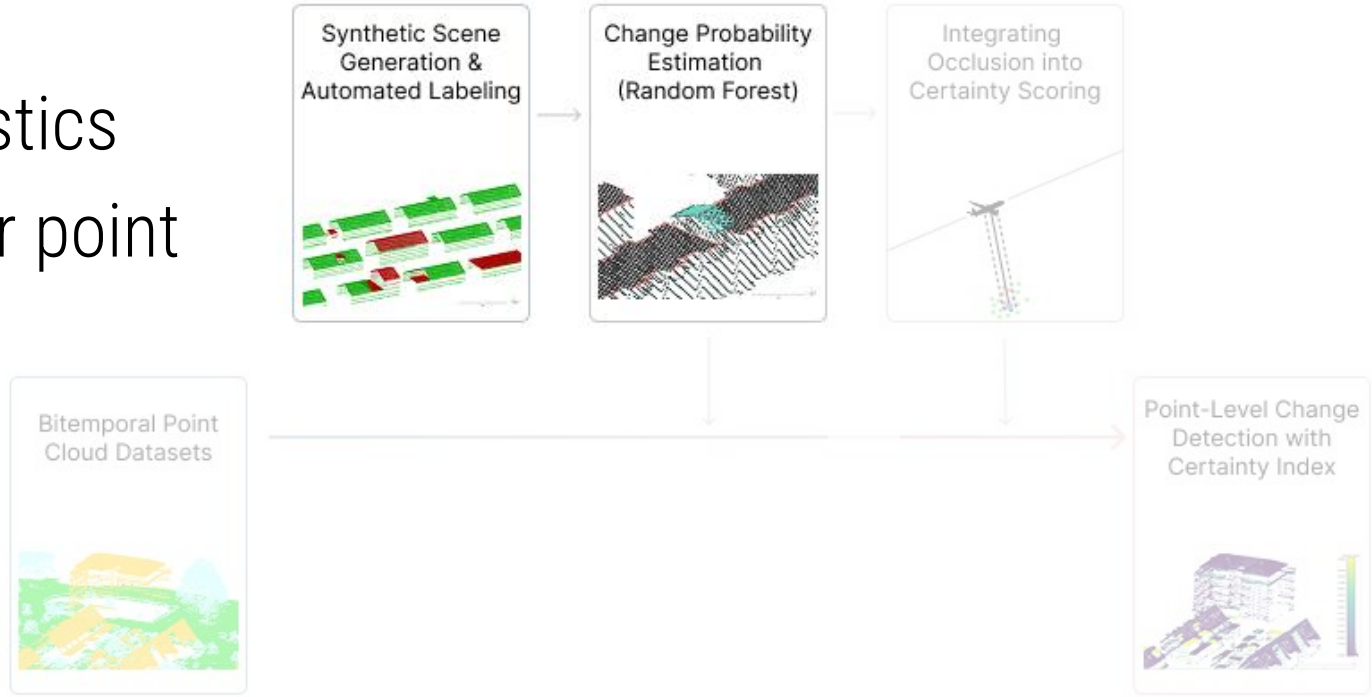
Change Probability Estimation

Motivation

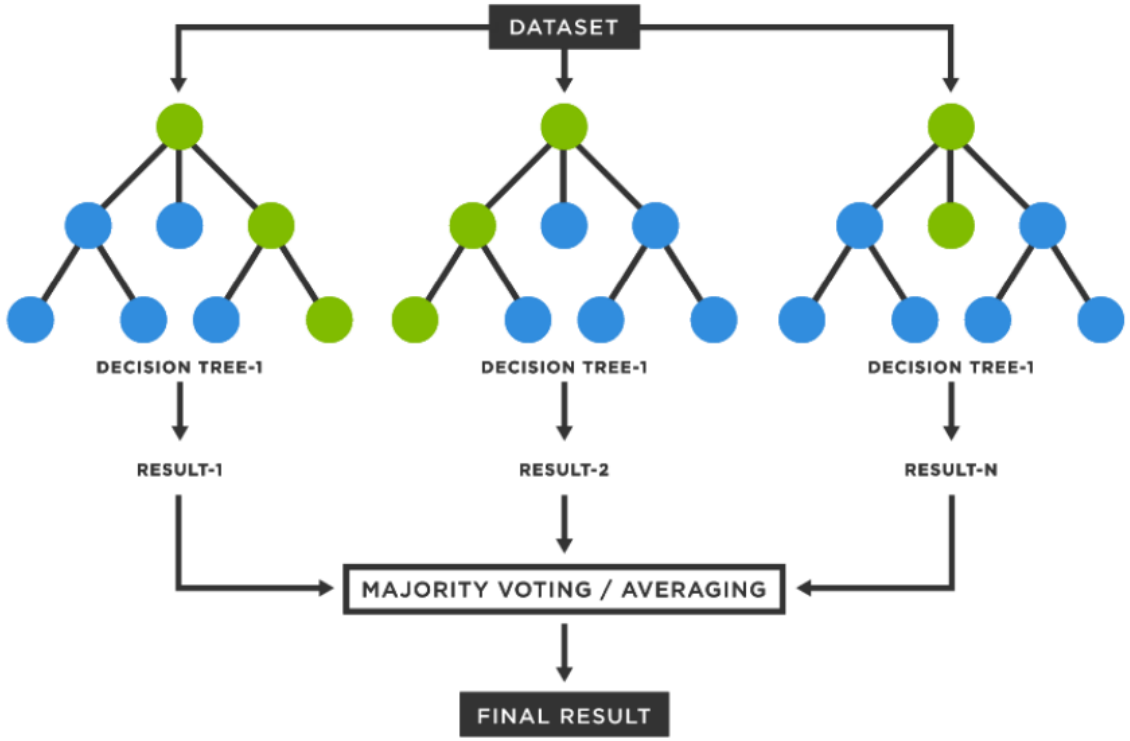
- Incorporate spatial characteristics
- Outputs a probability score per point



Change Probability Estimation

Random Forest Classifier

- Makes guesses on information
- Multiple decision trees
- Features



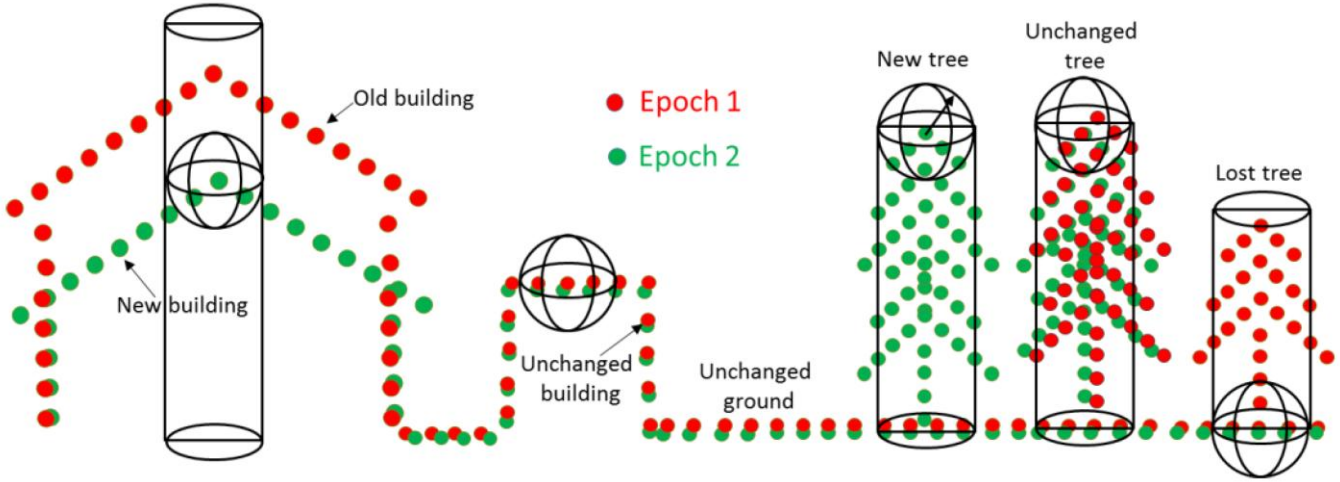
Source: Nofulla [2023]

Change Probability Estimation

Features

- Stability Factor Difference

$$\text{Stability Factor} = \frac{N_{\text{spherical}}}{N_{\text{cylindrical}}}$$

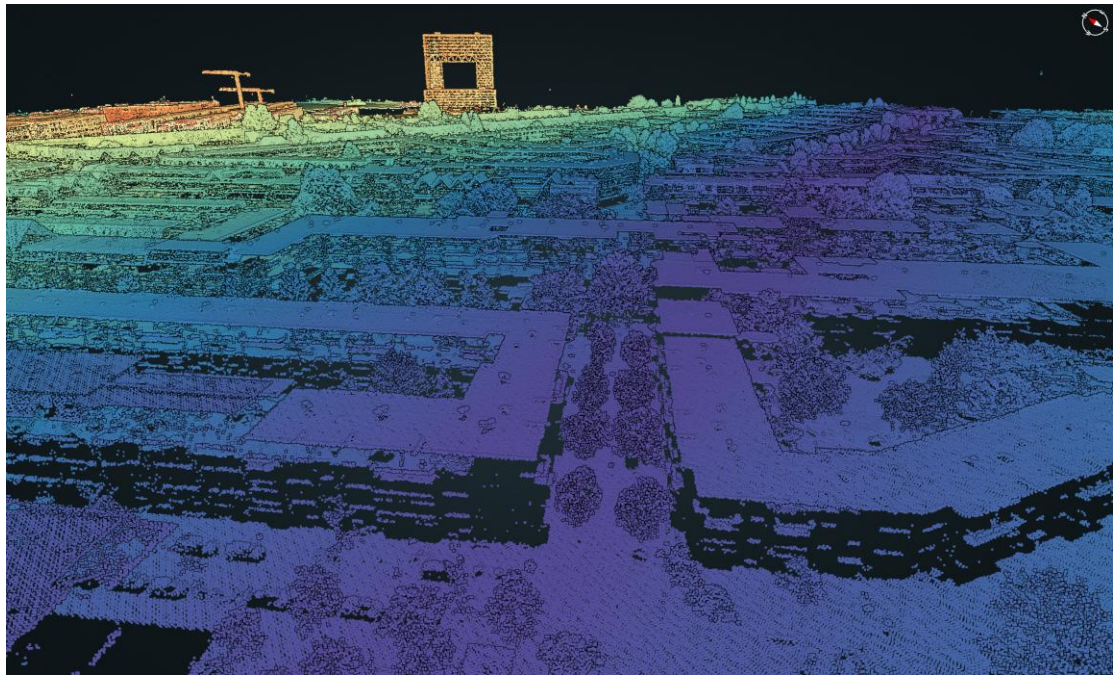


Source: Tran et al [2018]

Change Probability Estimation

Features

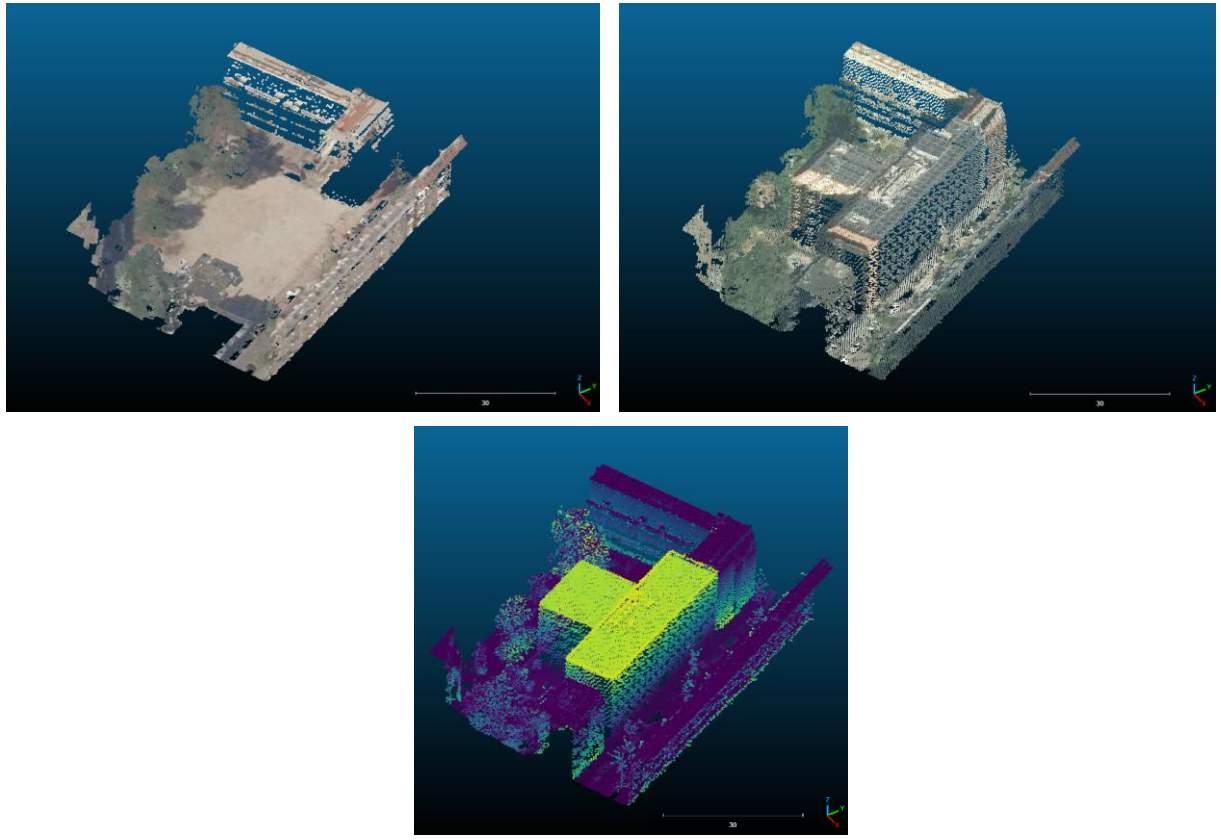
- Stability Factor Difference
- Distance to flightline



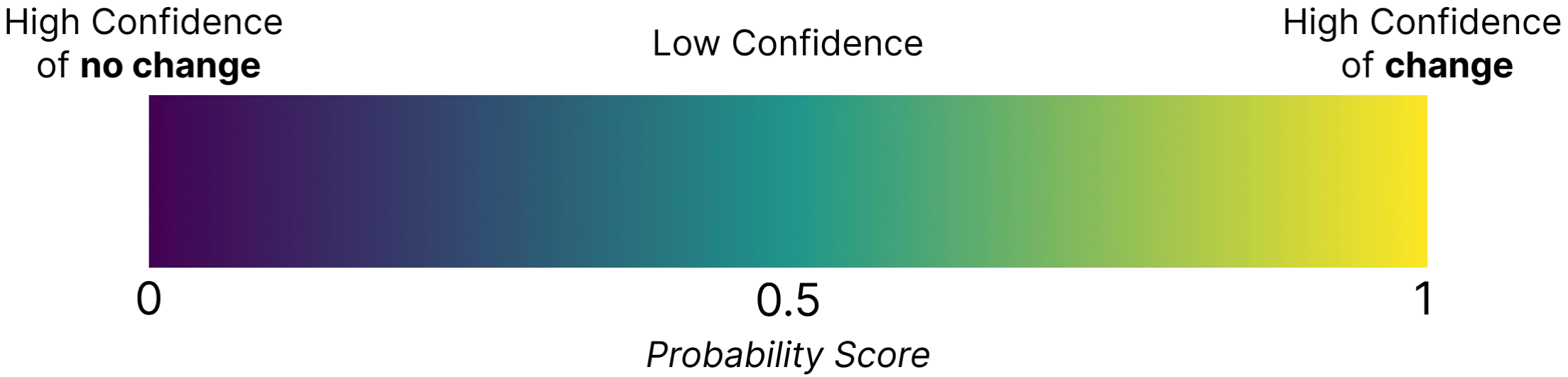
Change Probability Estimation

Features

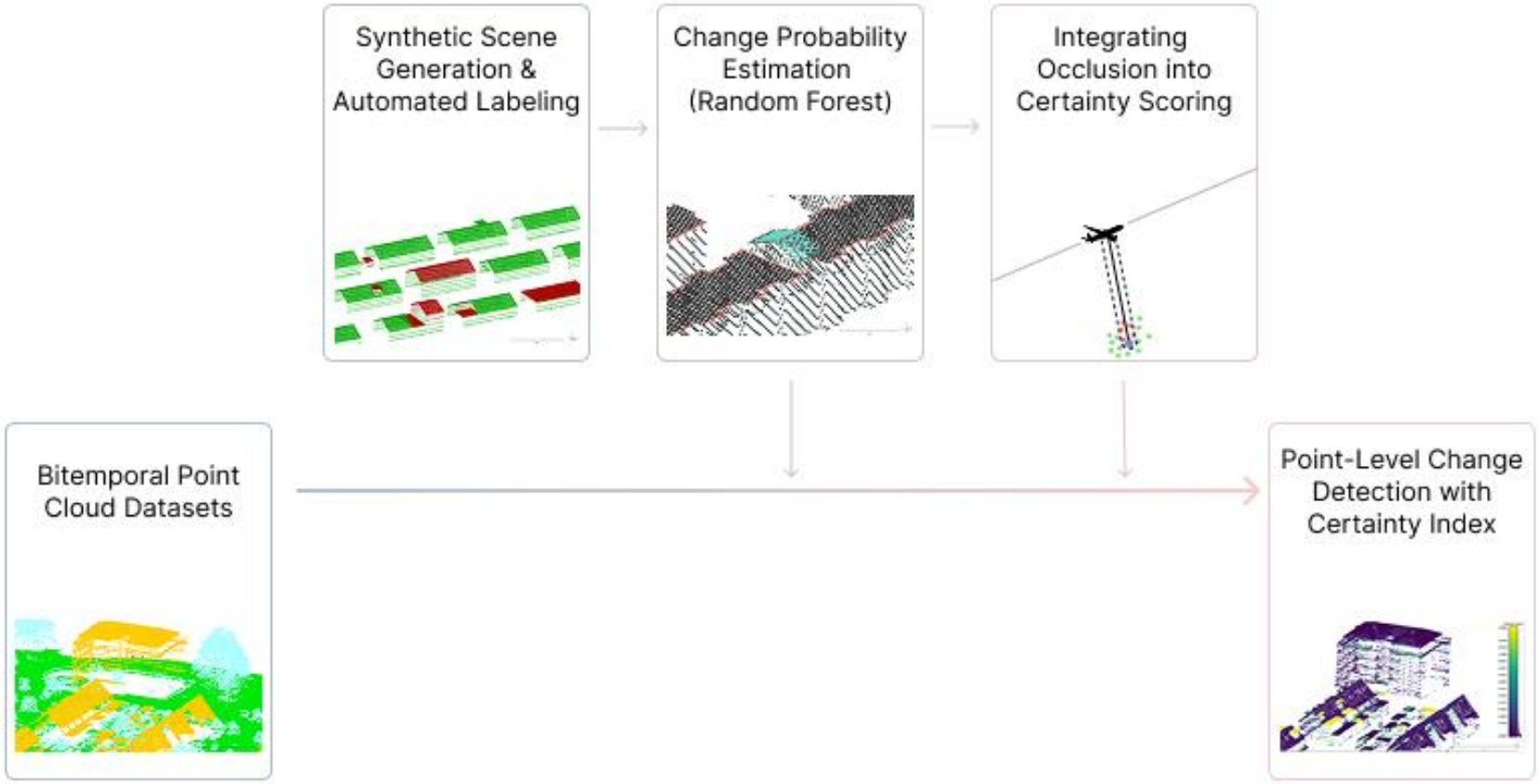
- Stability Factor Difference
- Distance to flightline
- Height difference



Change Probability Estimation



Overview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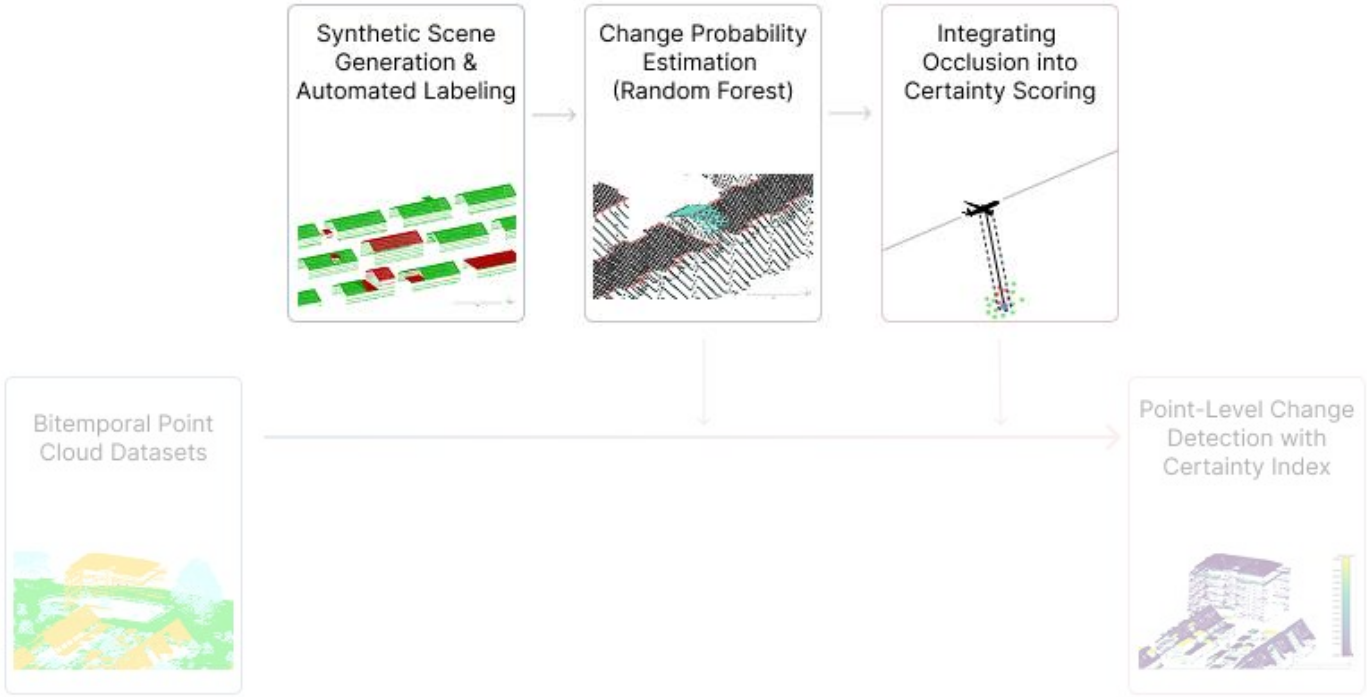
Integrating Occlusion into Certainty Score

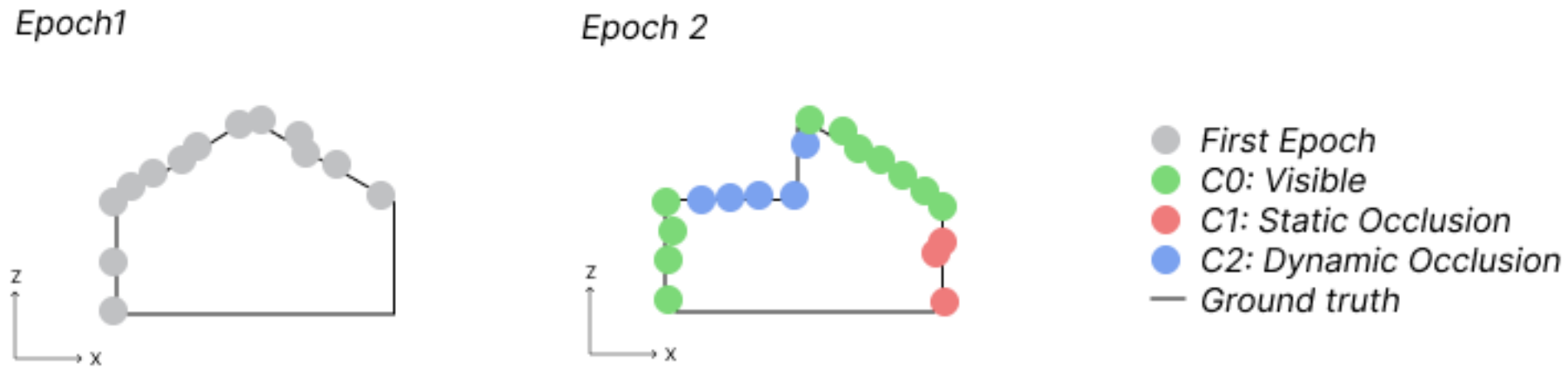
Motivation

- Handling occlusion at the point level



Integrating Occlusion into Certainty Score

1. Two types of occlusion

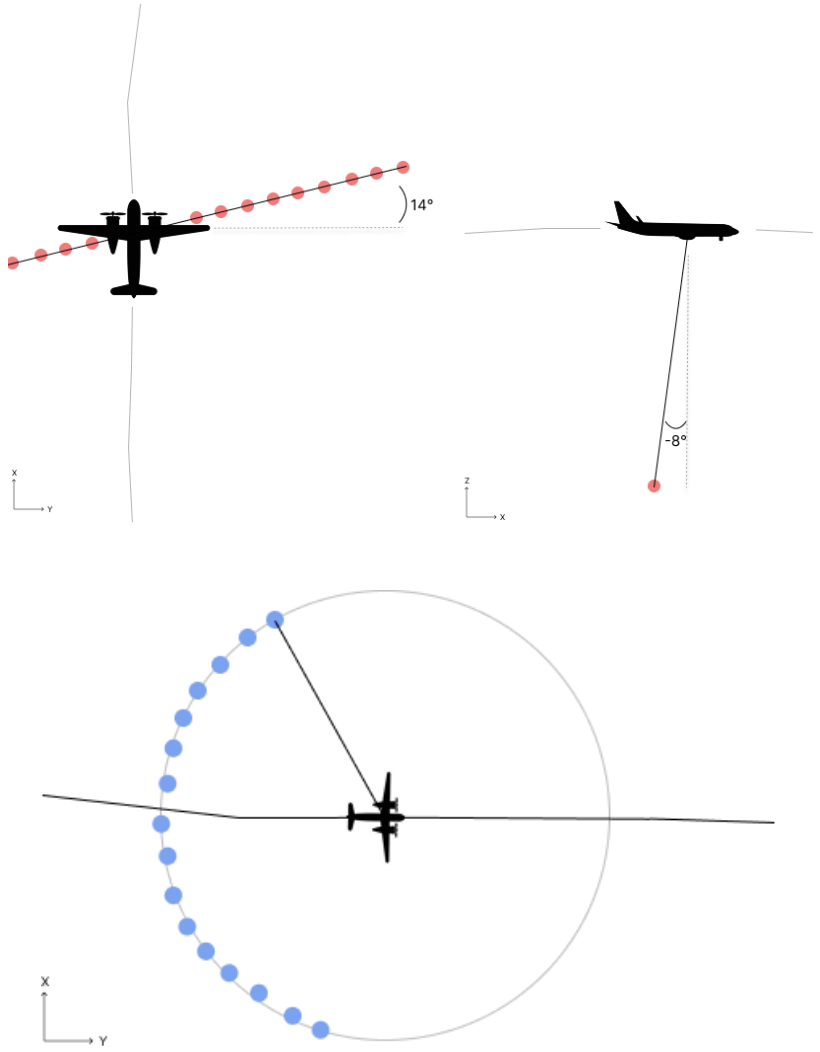


Integrating Occlusion into Certainty Score

1. Two types of occlusion
2. Calculate two Boolean checks
   - Boolean 1: Is the point hidden when using the point cloud and **aircraft positions** from **epoch 1**?
   - Boolean 2: Is the point hidden when using the point cloud from epoch 1 but the **aircraft positions** from **epoch 2**?

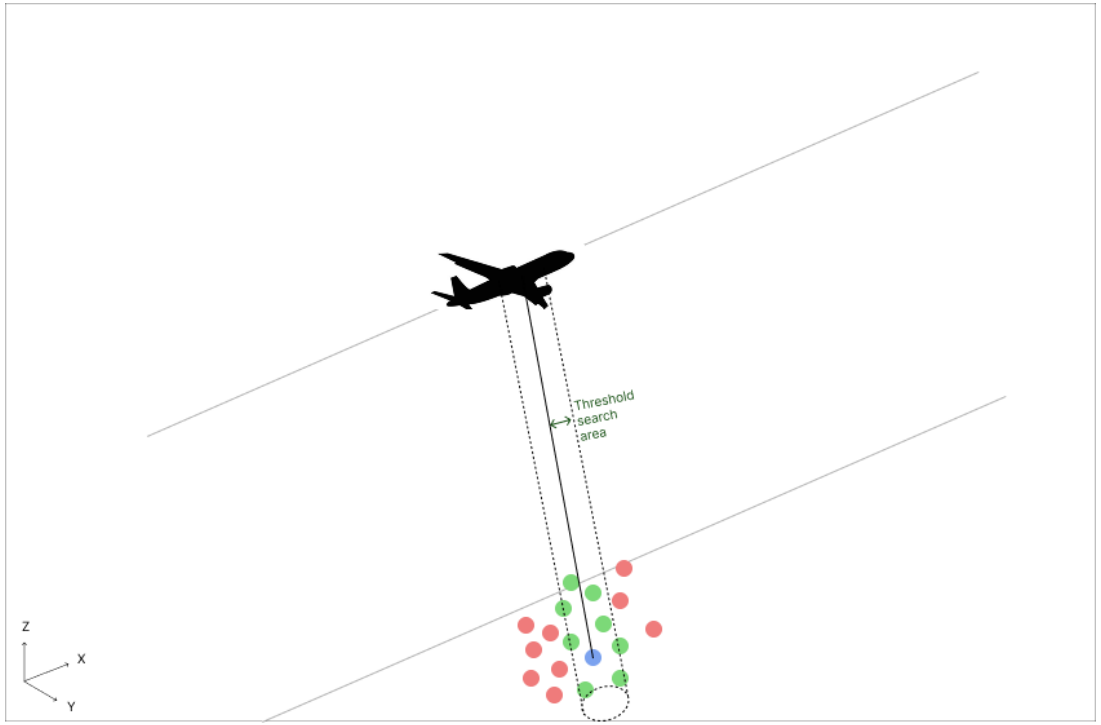
Integrating Occlusion into Certainty Score

1. Two types of occlusion
2. Calculate two Boolean checks
   - Determine aircraft positions



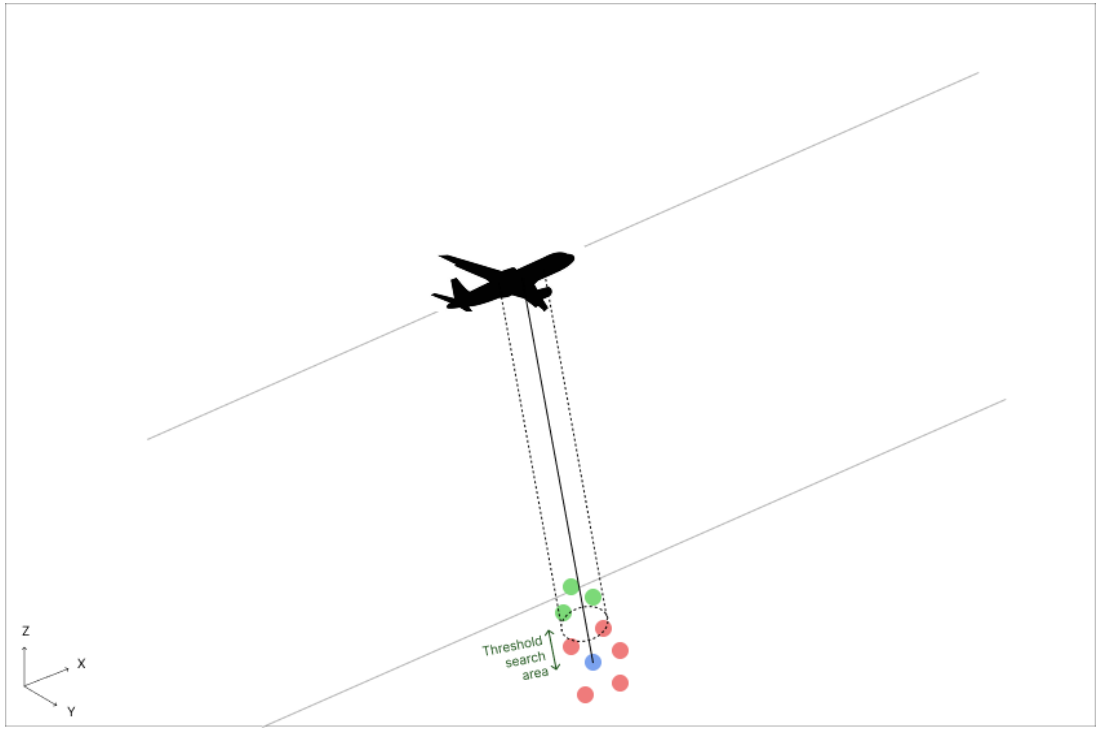
Integrating Occlusion into Certainty Score

1. Two types of occlusion
2. Calculate two Boolean checks
   - Determine aircraft positions
   - Selecting Relevant Points



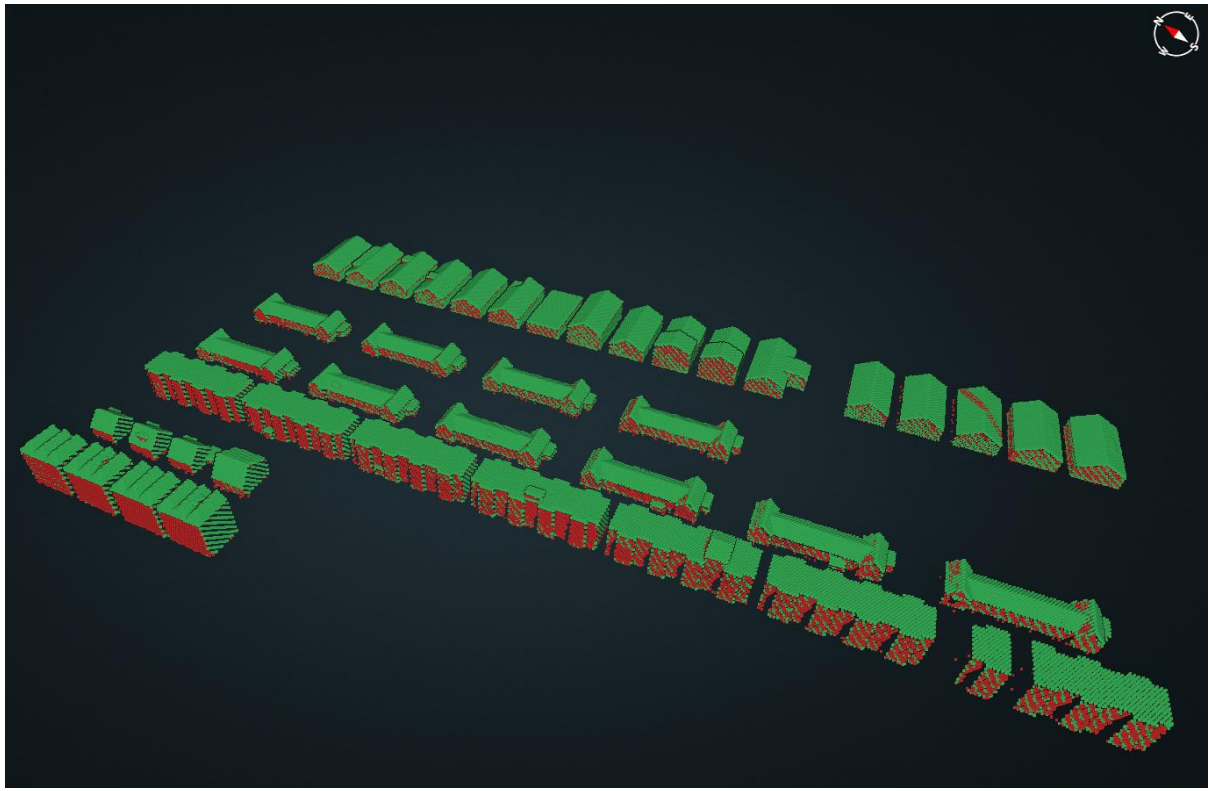
Integrating Occlusion into Certainty Score

1. Two types of occlusion
2. Calculate two Boolean checks
   - Determine aircraft positions
   - Selecting Relevant Points
   - Determining Occlusion



Integrating Occlusion into Certainty Score

1. Two types of occlusion
2. Calculate two Boolean checks
3. Determine certainty score
   - Know occlusion type point
   - Know stability factor point



Integrating Occlusion into Certainty Score

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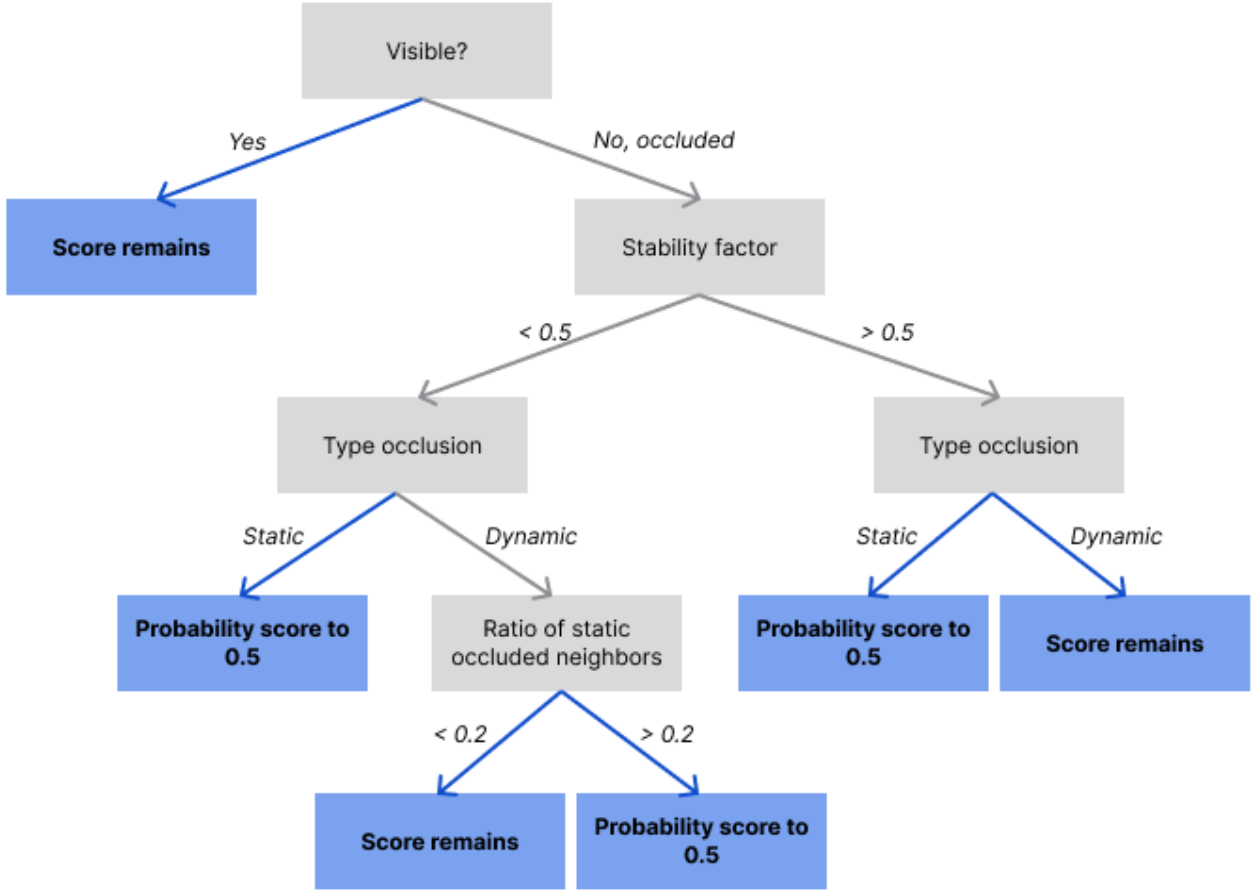
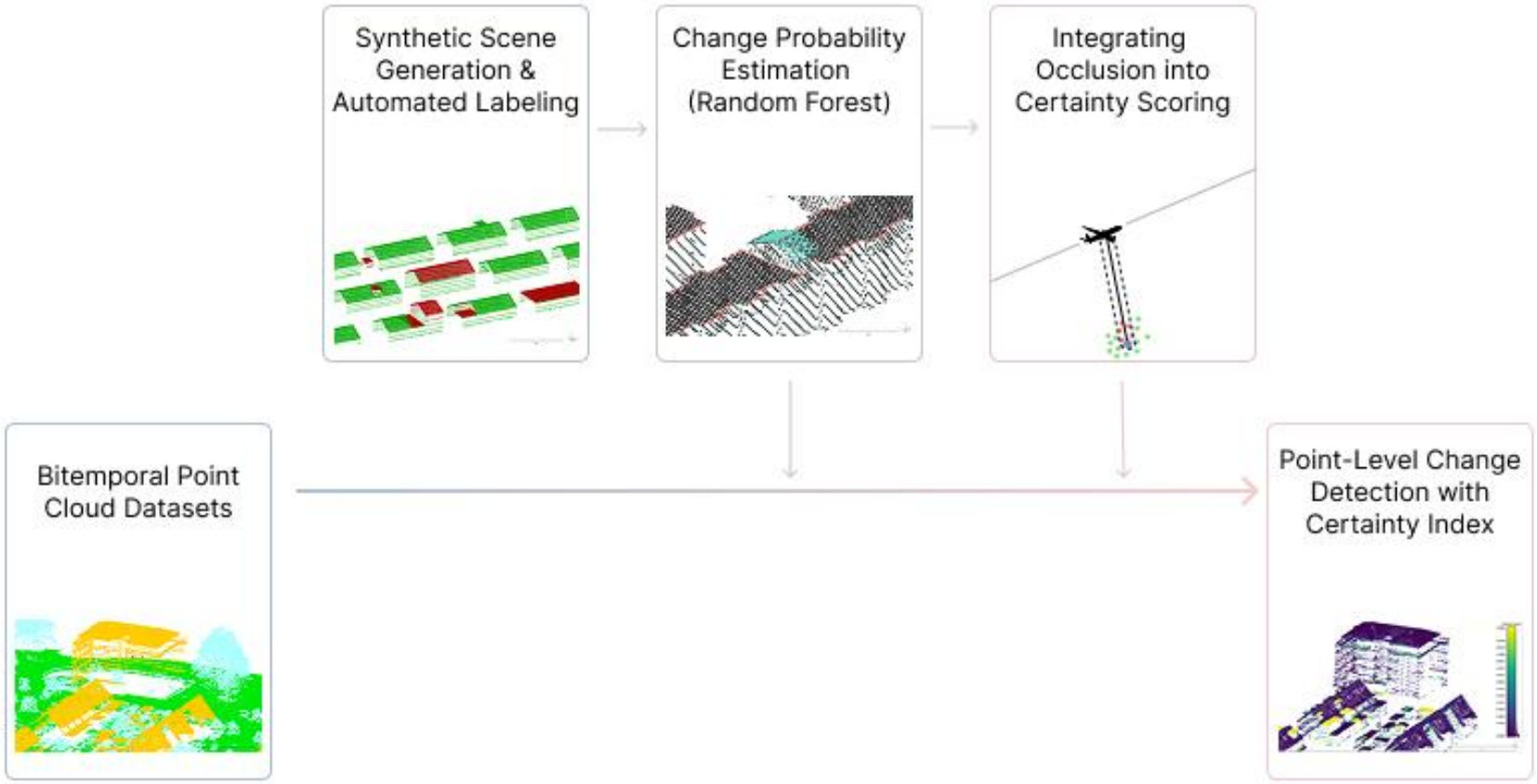


Overview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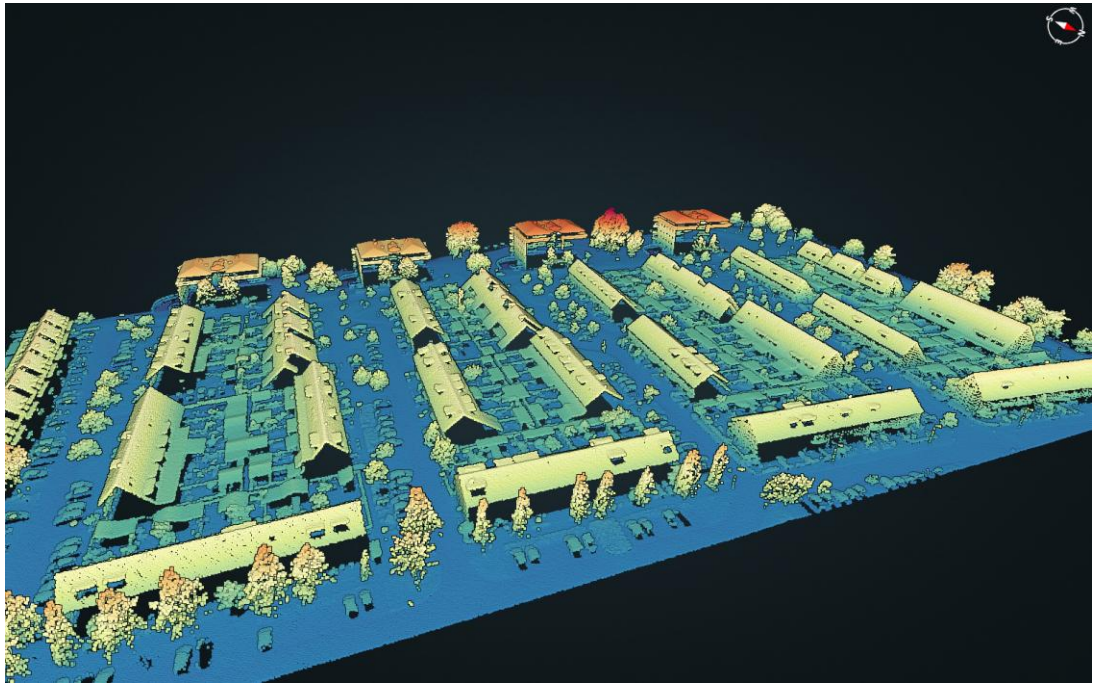
Overview

- Assessment occlusion detection and integration
- Performance certainty score

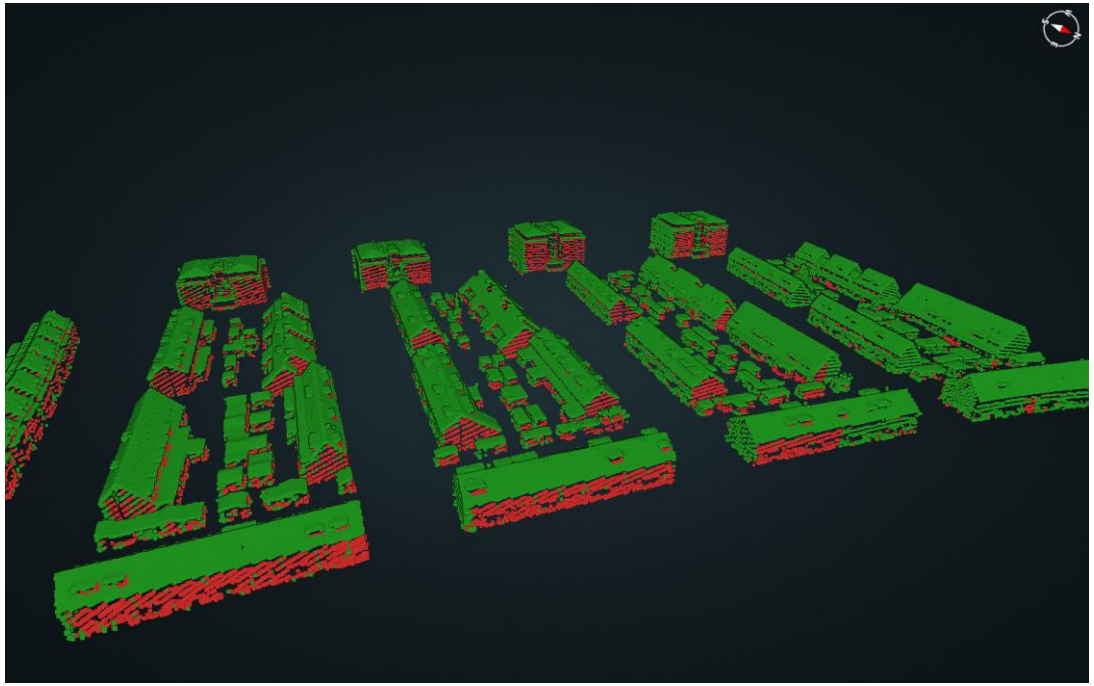
Assessment Occlusion Detection

AHN4



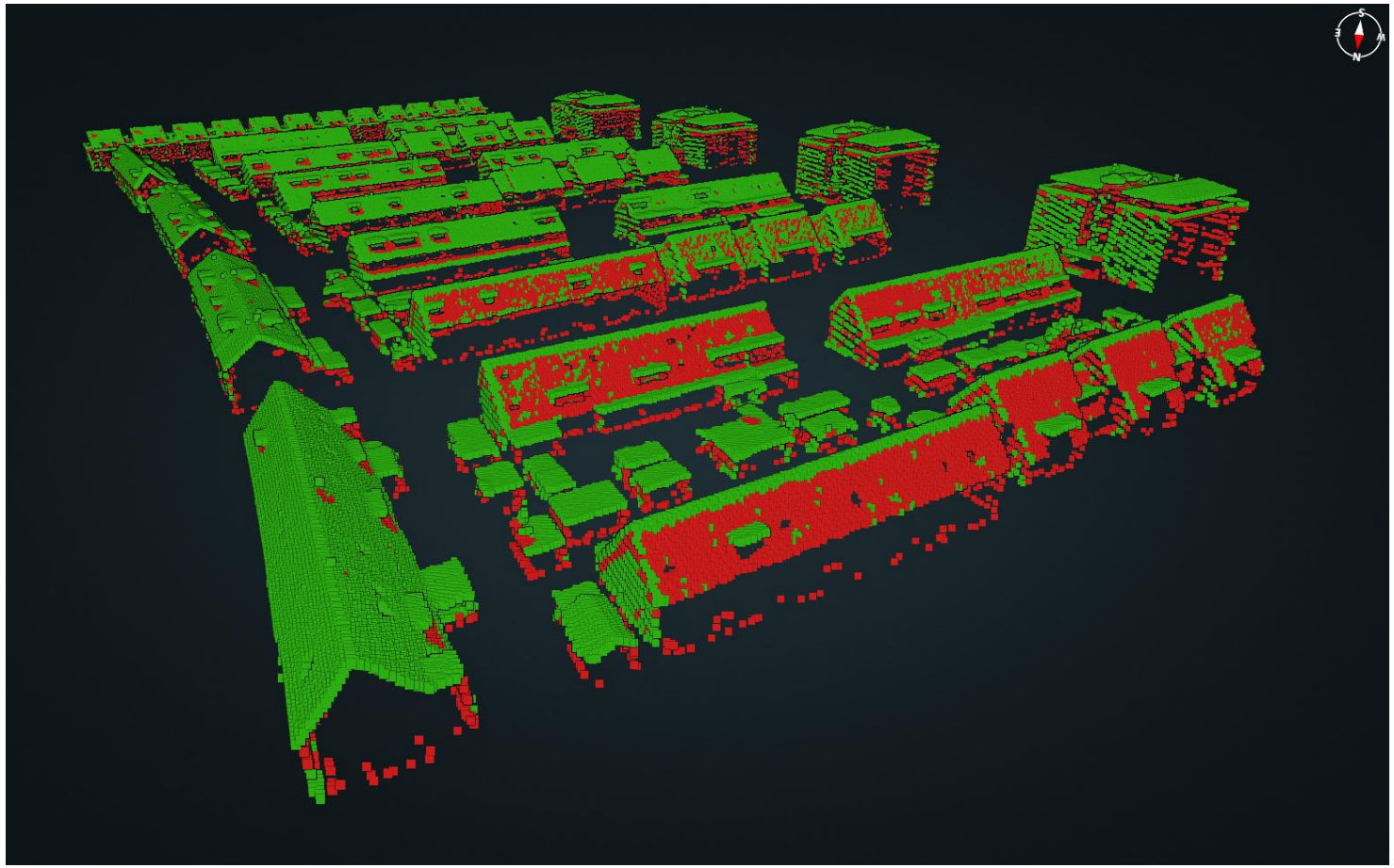
colored height elevation

AHN5



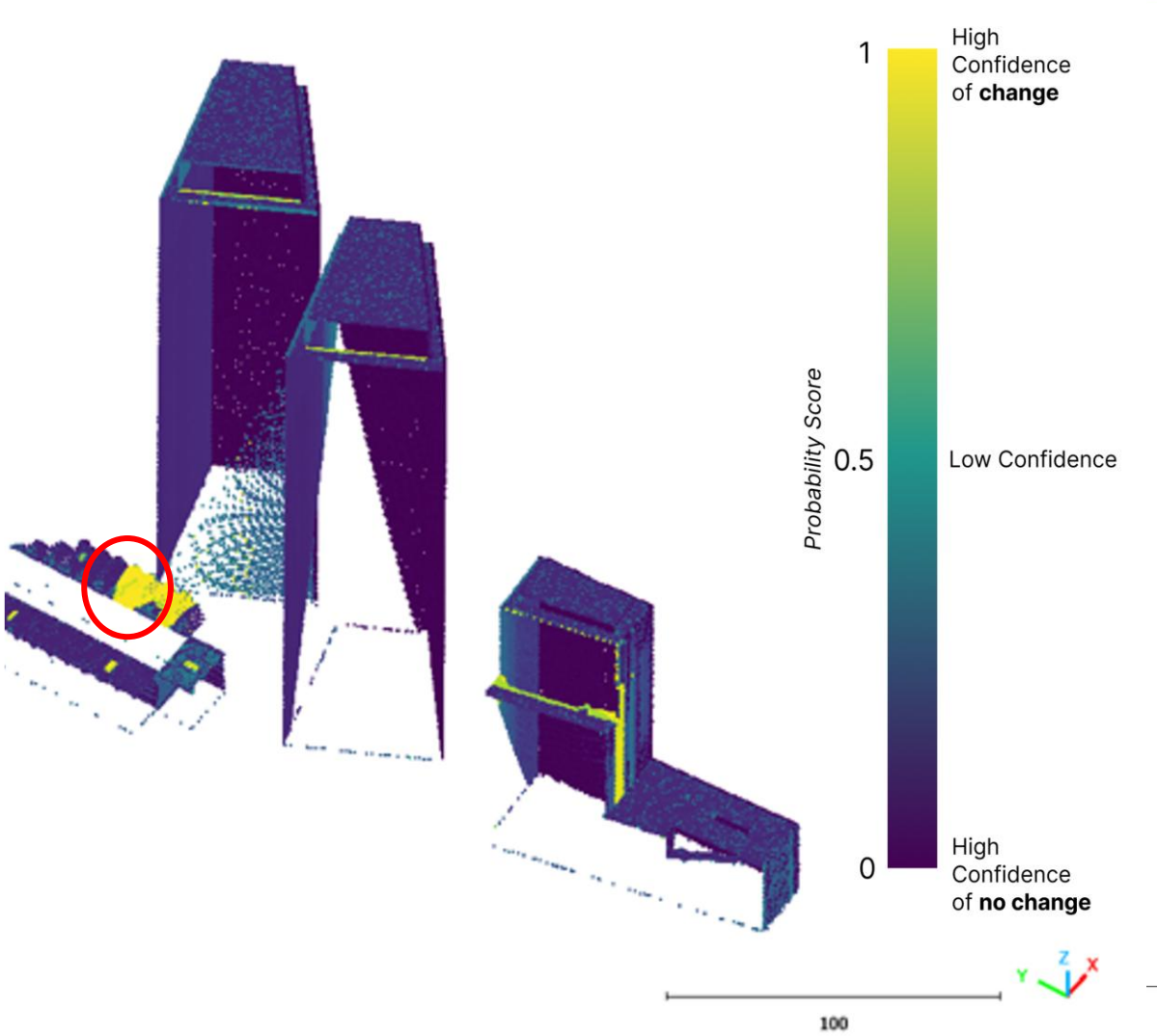
- Visible in Boolean 1
- Not visible in Boolean 1

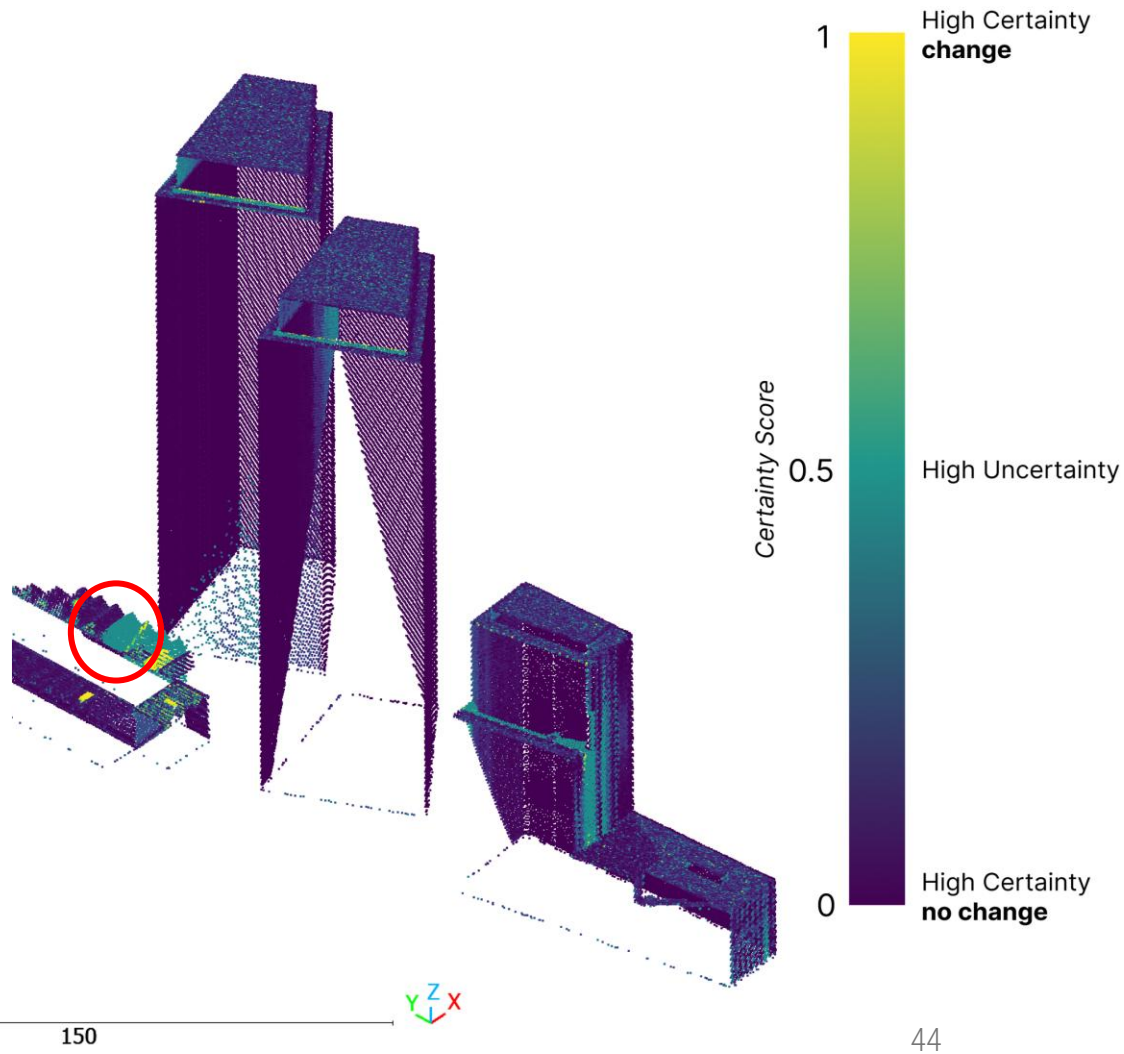
Assessment Occlusion Detection



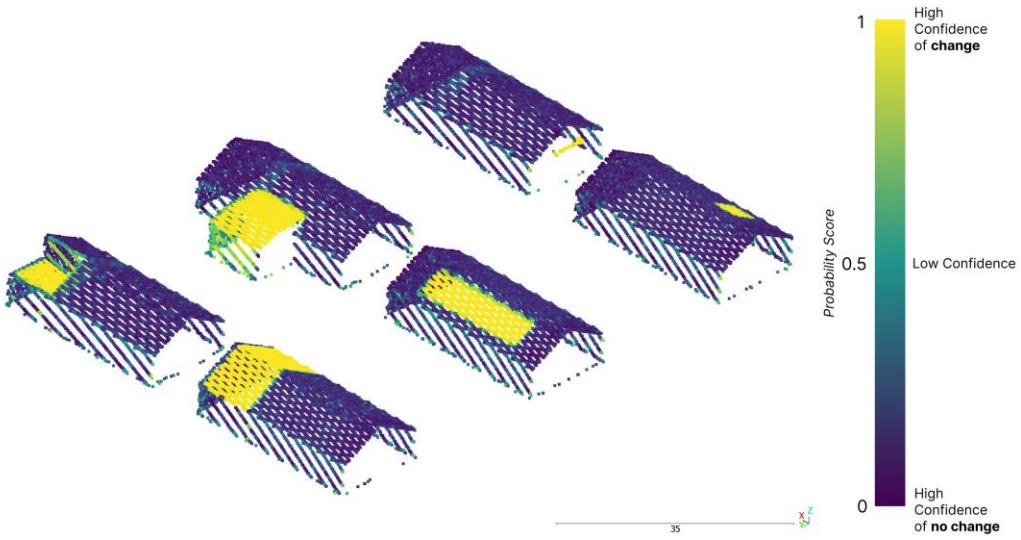
Visible in Boolean 2
Not visible in Boolean 2

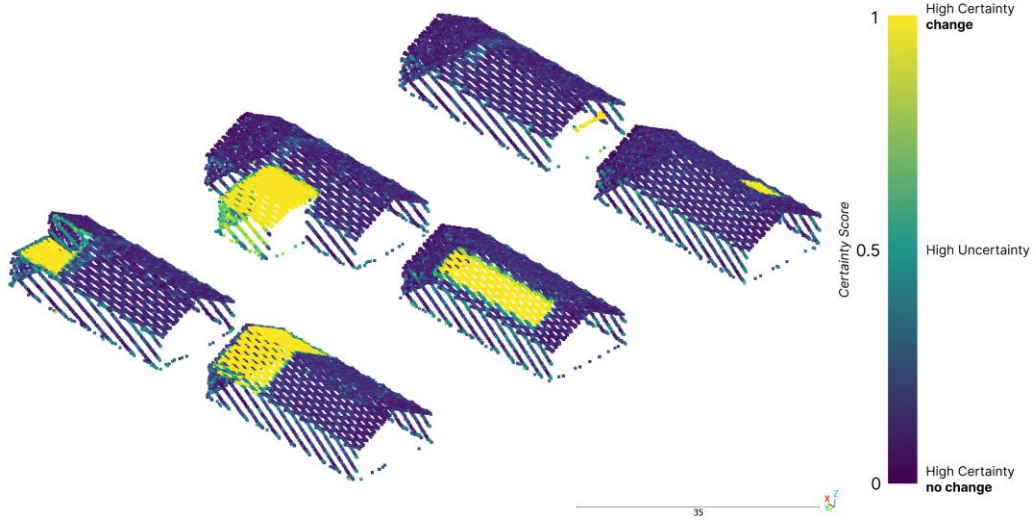
Assessment Static Occlusion Integration





Assessment Dynamic Occlusion Integration



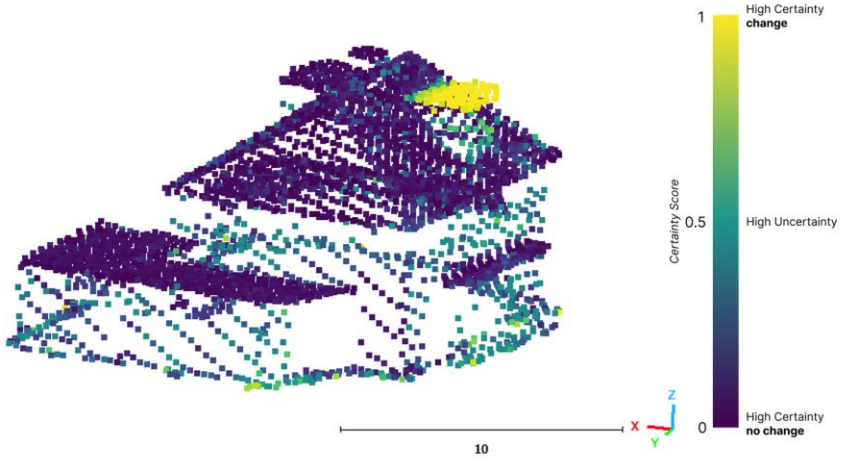


Overview

- Assessment occlusion detection and integration
- Performance certainty score

Performance certainty score

Source: Beeldmateriaal.nl



Performance certainty score

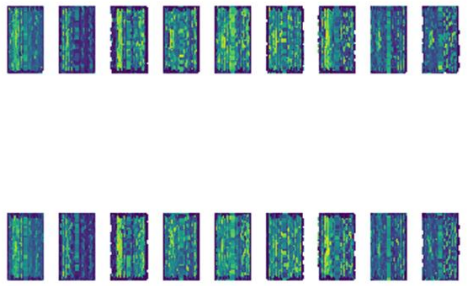
Source: Beeldmateriaal.nl

Performance certainty score

- Synthetic scene and real scene similar results
- Building changes detected with high certainty
- Solar panels on angled roof detected; flat ones less reliable
- Temporary objects often classified as structural changes
- Occluded walls become uncertain
- Rotterdam datasets clearer results

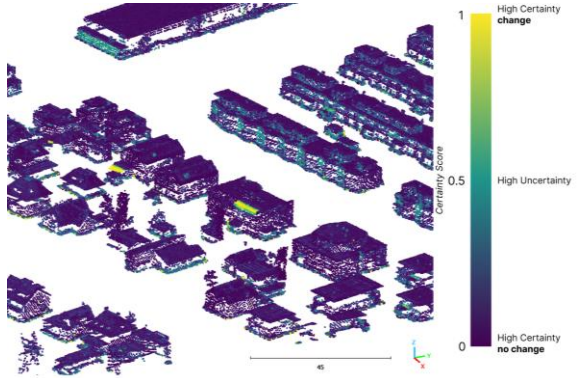
Limitations

1.



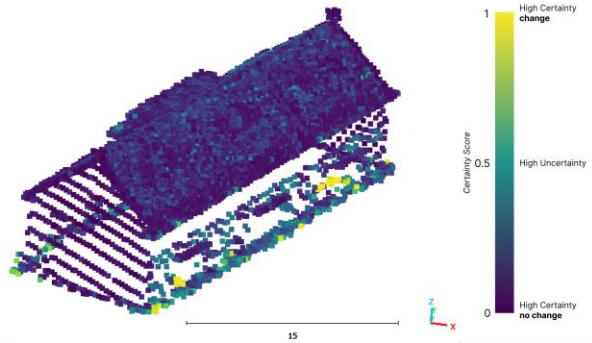
Training dataset excluded small height changes of < 12 cm

2.



Assessment on real data are only visual

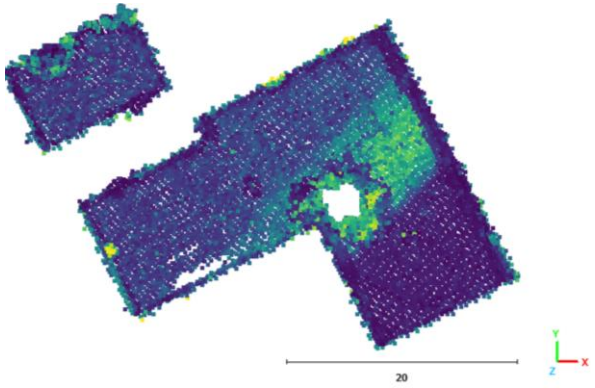
3.



Computationally intensive

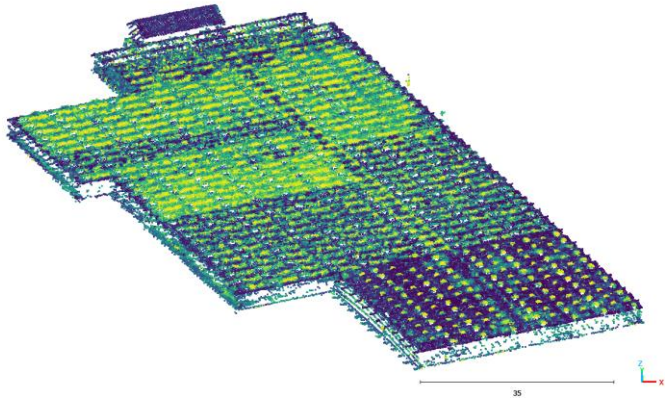
Limitations

4.



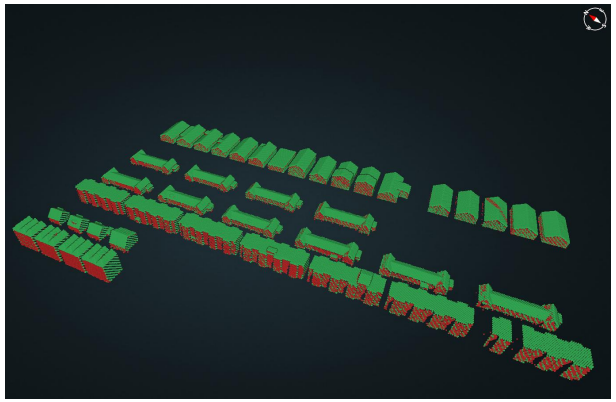
Distance to the flightline between 129 and 138 meter

5.



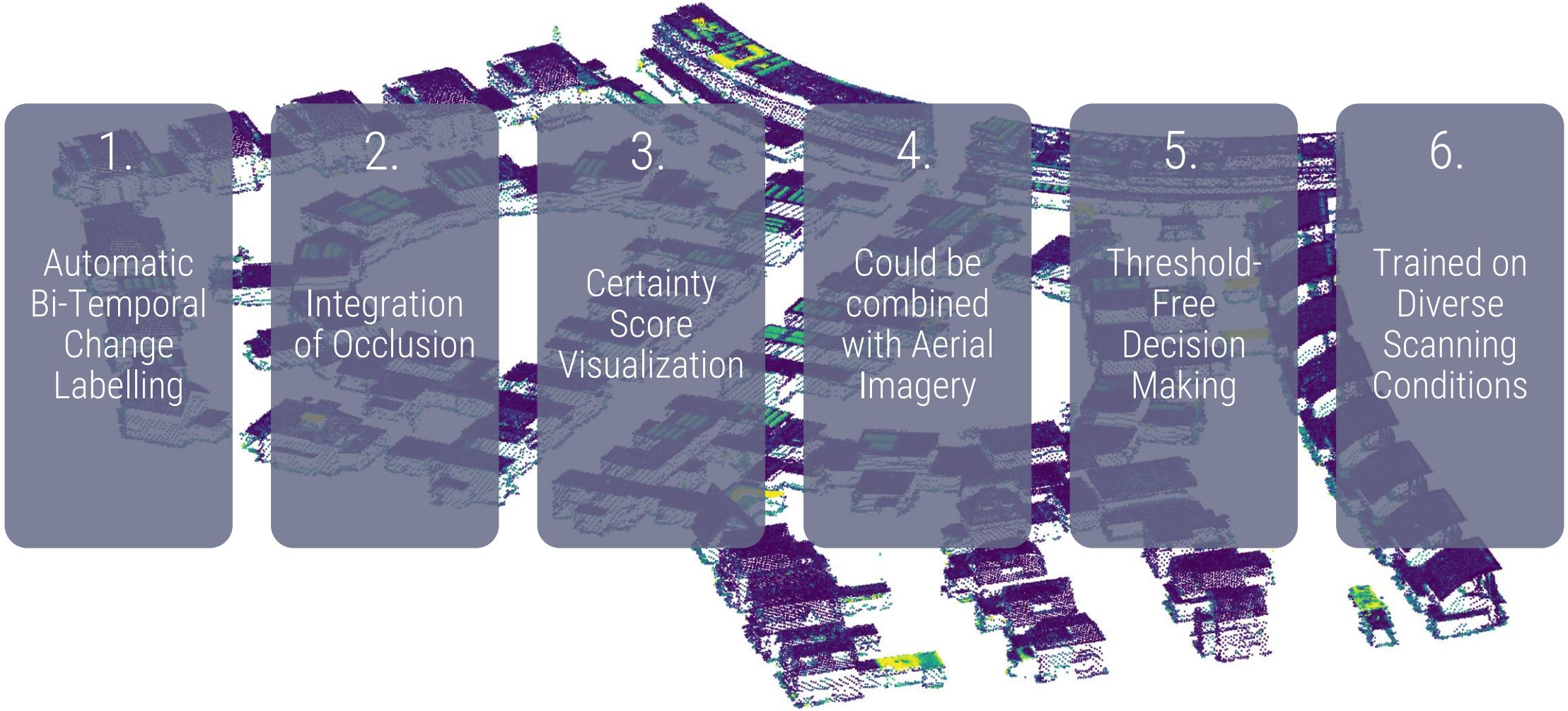
Stability factor: Glass roof surfaces

6.



Occlusion: Difficulty with walls

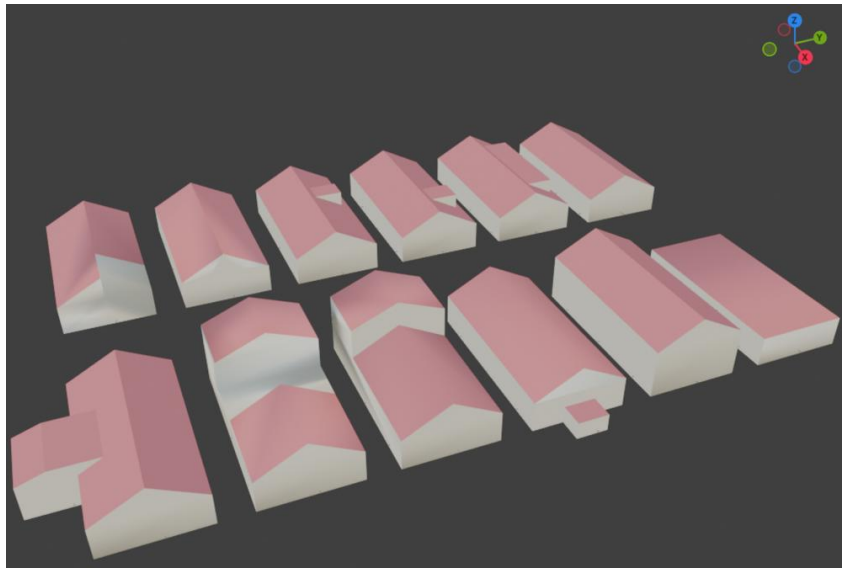
Key aspects this research



1. Automatic Bi-Temporal Change Labelling
2. Integration of Occlusion
3. Certainty Score Visualization
4. Could be combined with Aerial Imagery
5. Threshold-Free Decision Making
6. Trained on Diverse Scanning Conditions

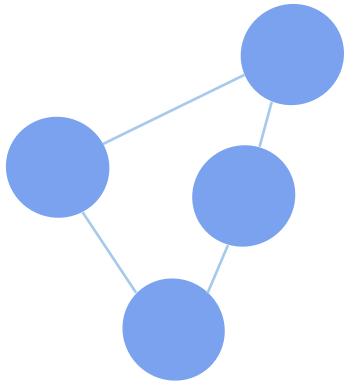
Within the Scope of This Study

Pre-Evaluation at Building Level

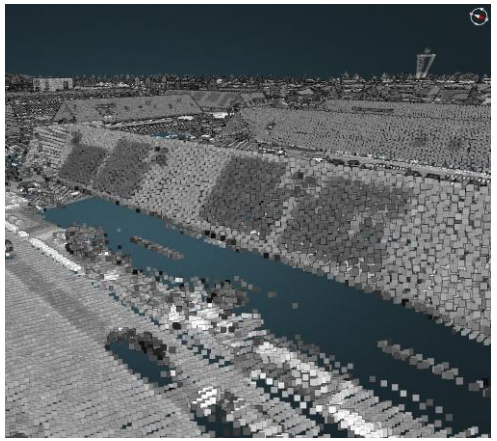


Expanding Scene Variability

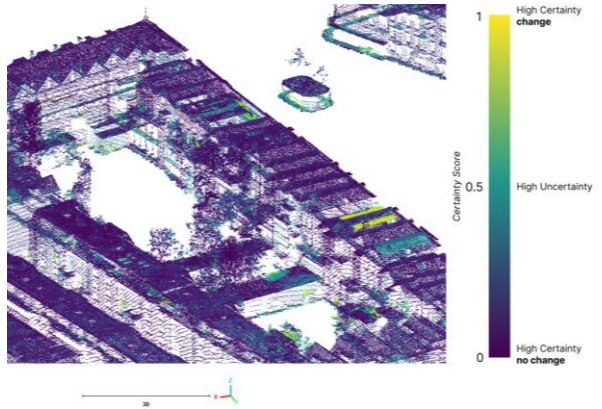
Future Directions for Other Researchers



Graph Neural Networks for Context-Aware Classification



Use of Intensity and Color Information

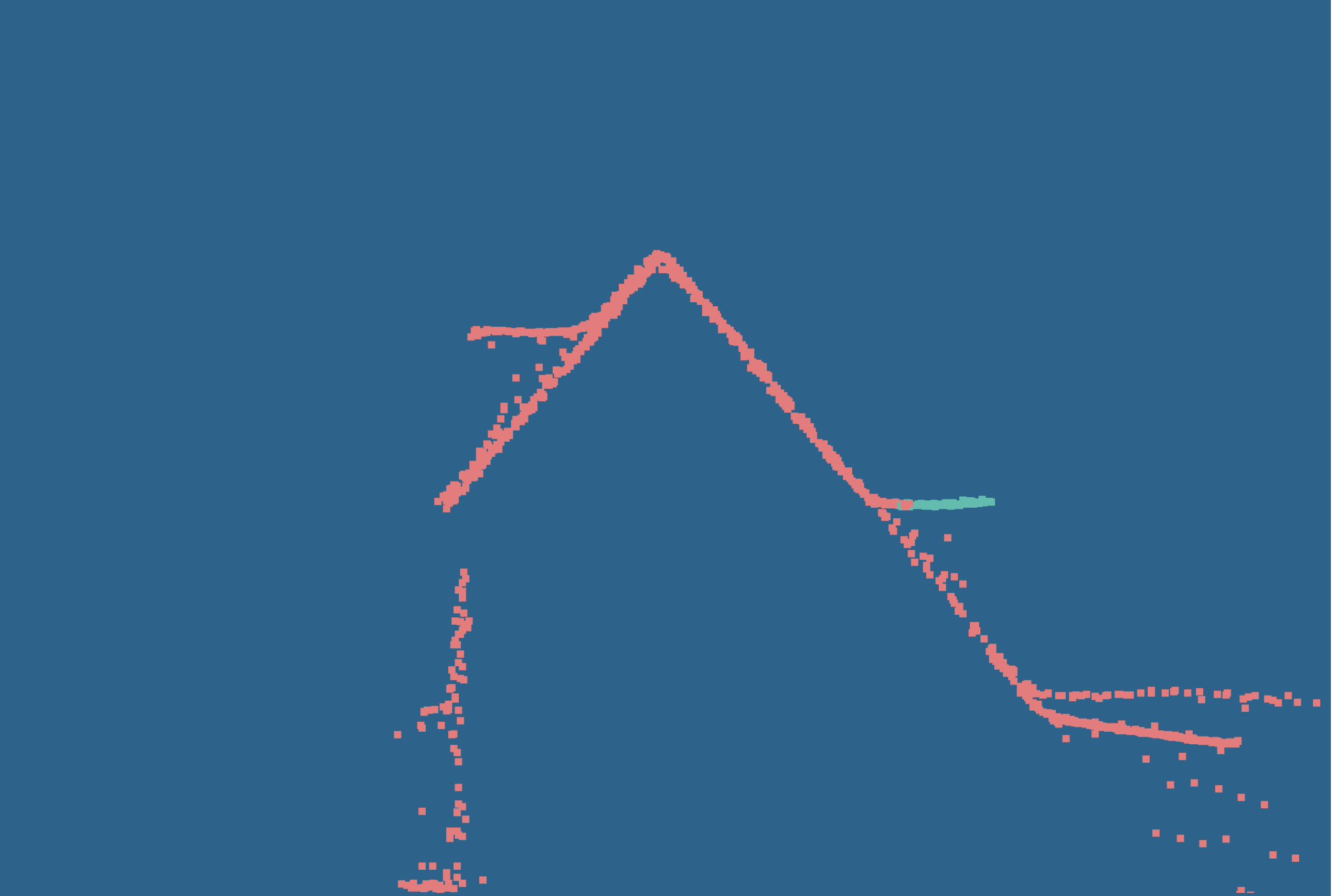


Extent Certainty Index

References Figures

Nofulla, J. (2023). Deep Learning-based Change Detection and Classification for Airborne Laser Scanning Data.

Tran, T. H. G., Ressl, C., and Pfeifer, N. (2018). Integrated Change Detection and Classification in Urban Areas Based on Airborne Laser Scanning Point Clouds. Sensors, 18(2):448. Number: 2 Publisher: Multidisciplinary Digital Publishing Institute.



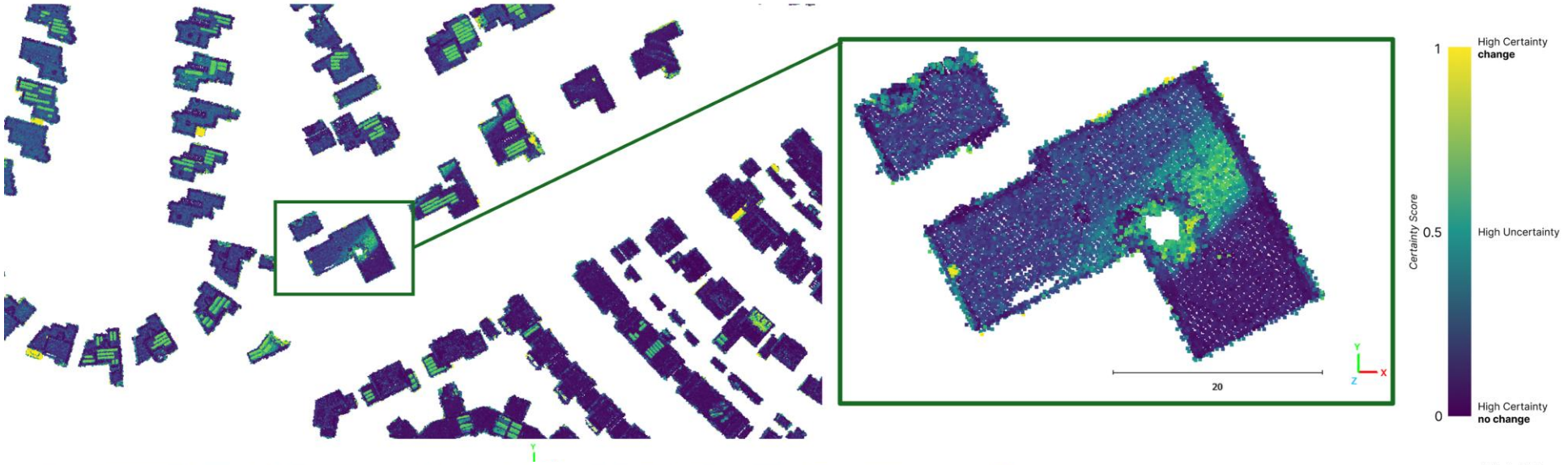
GEODELTA

TU Delft

Extra slide

2022
2024
High Certainty change
High Uncertainty
High Certainty no change
Certainty Score
1
0.5
0
15
2021
2024
High Certainty change
High Uncertainty
High Certainty no change
Certainty Score
1
0.5
0
20

Extra slide

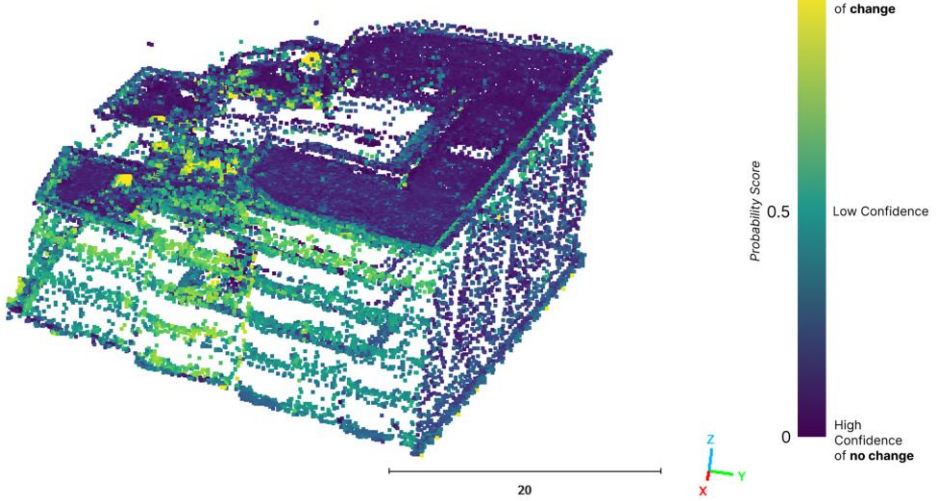

20
1
High Certainty
change
Certainty Score
0.5
High Uncertainty
0
High Certainty
no change

2021
BURGEMEESTER WILMINKHOF
2024
BURGEMEESTER WILMINKHOF
NOL VAN HATTUMHOF

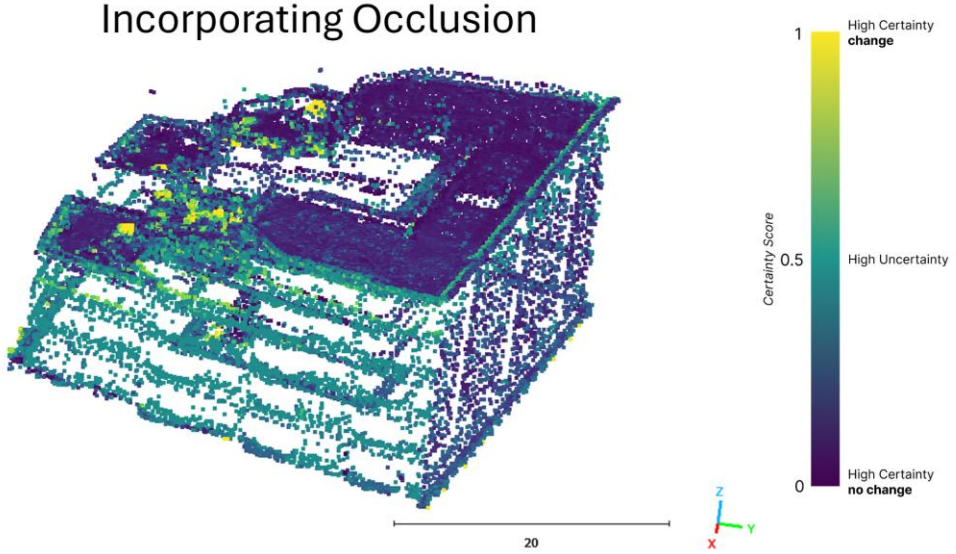
30
1
High Certainty
change
Certainty Score
0.5
High Uncertainty
0
High Certainty
no change

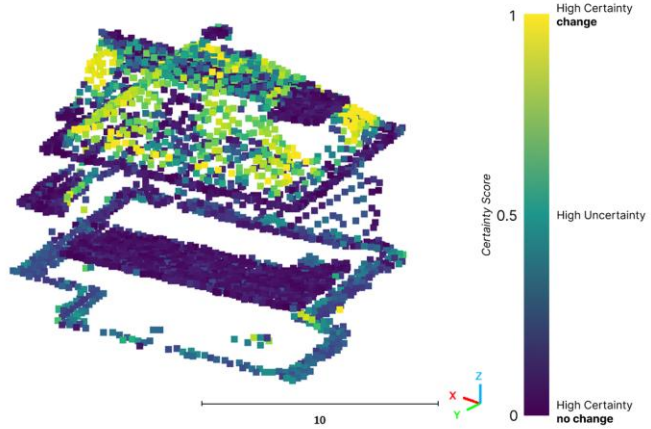
Extra slide

Random Forest outcome



Incorporating Occlusion





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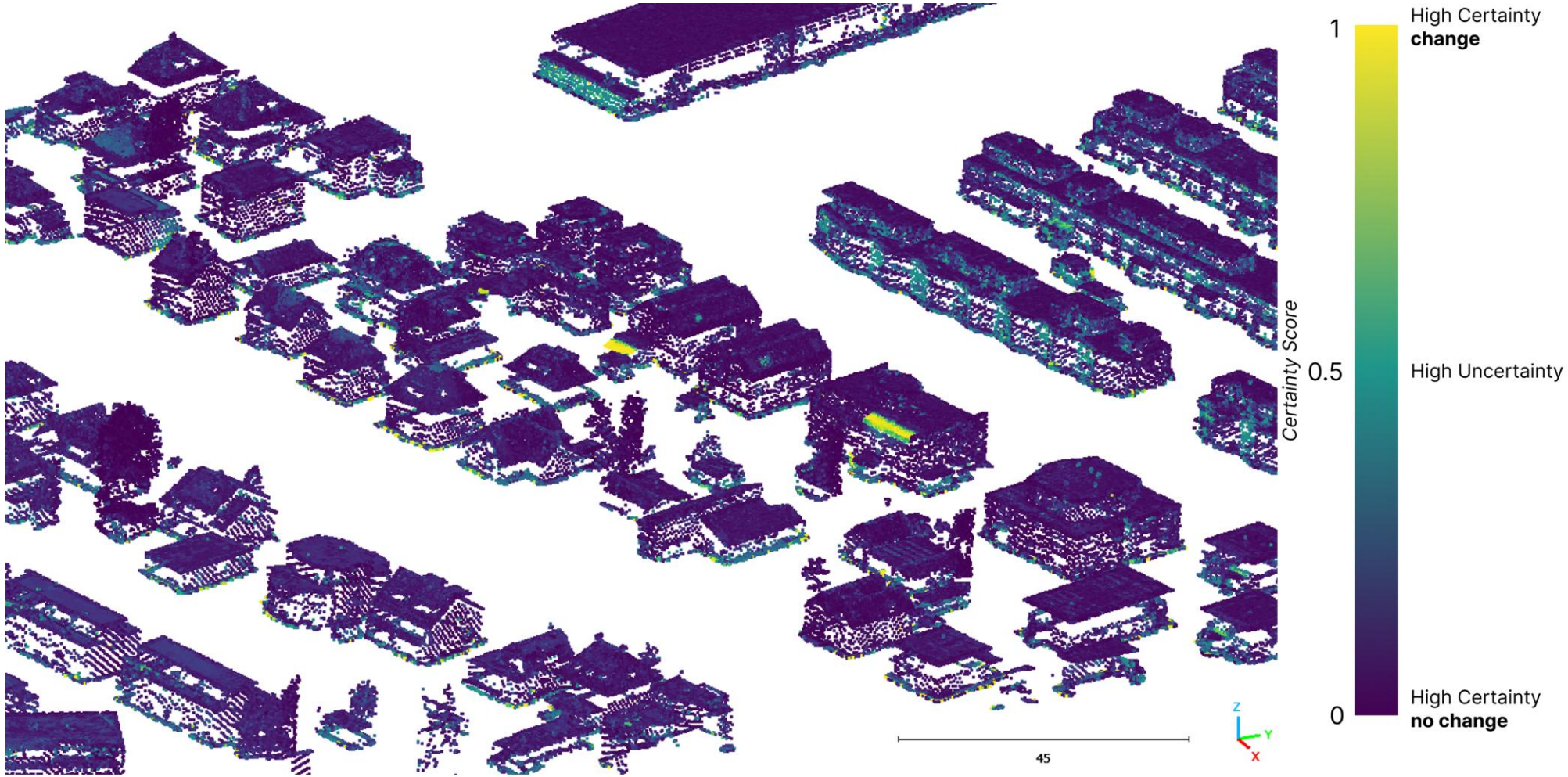
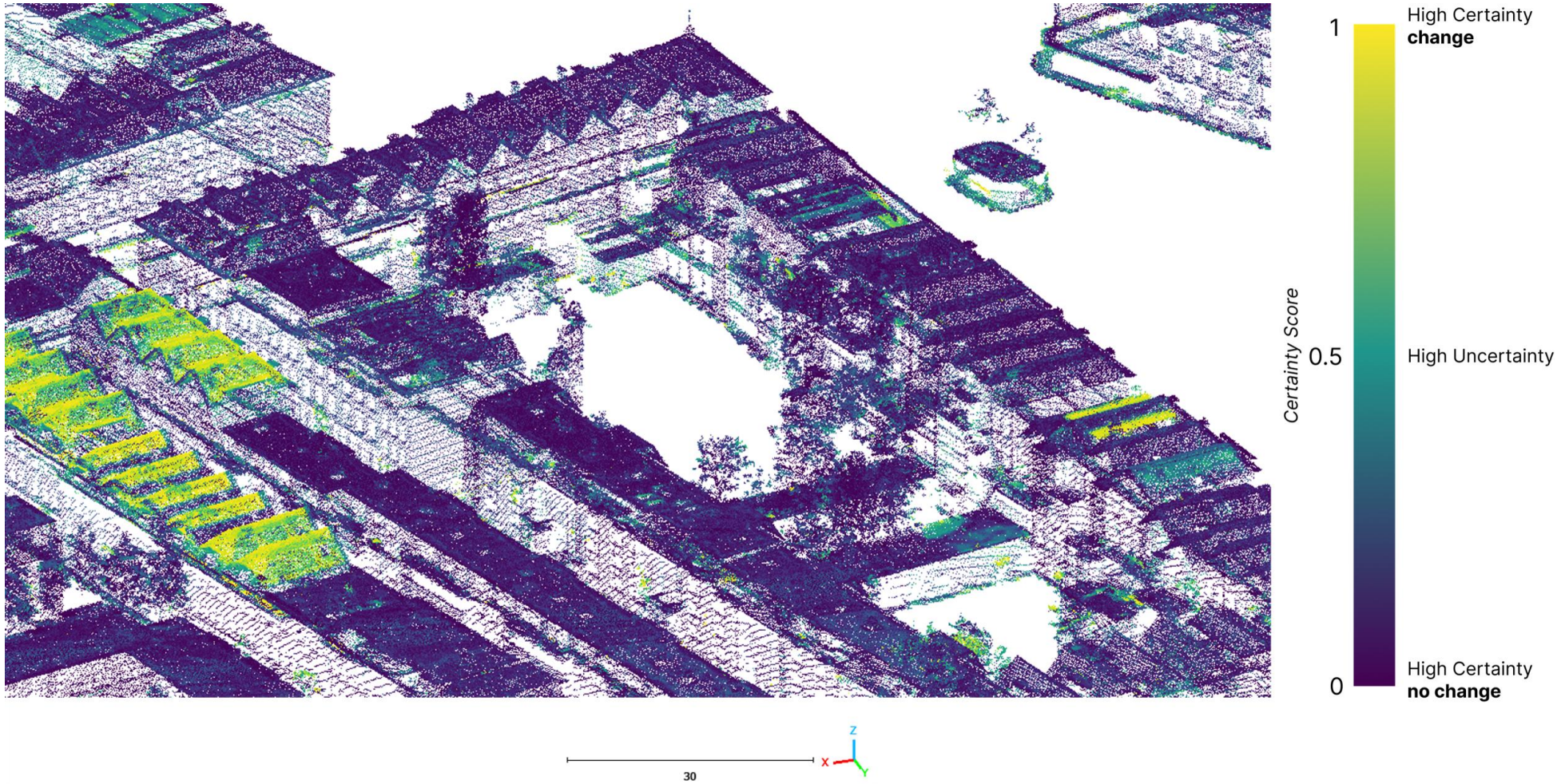
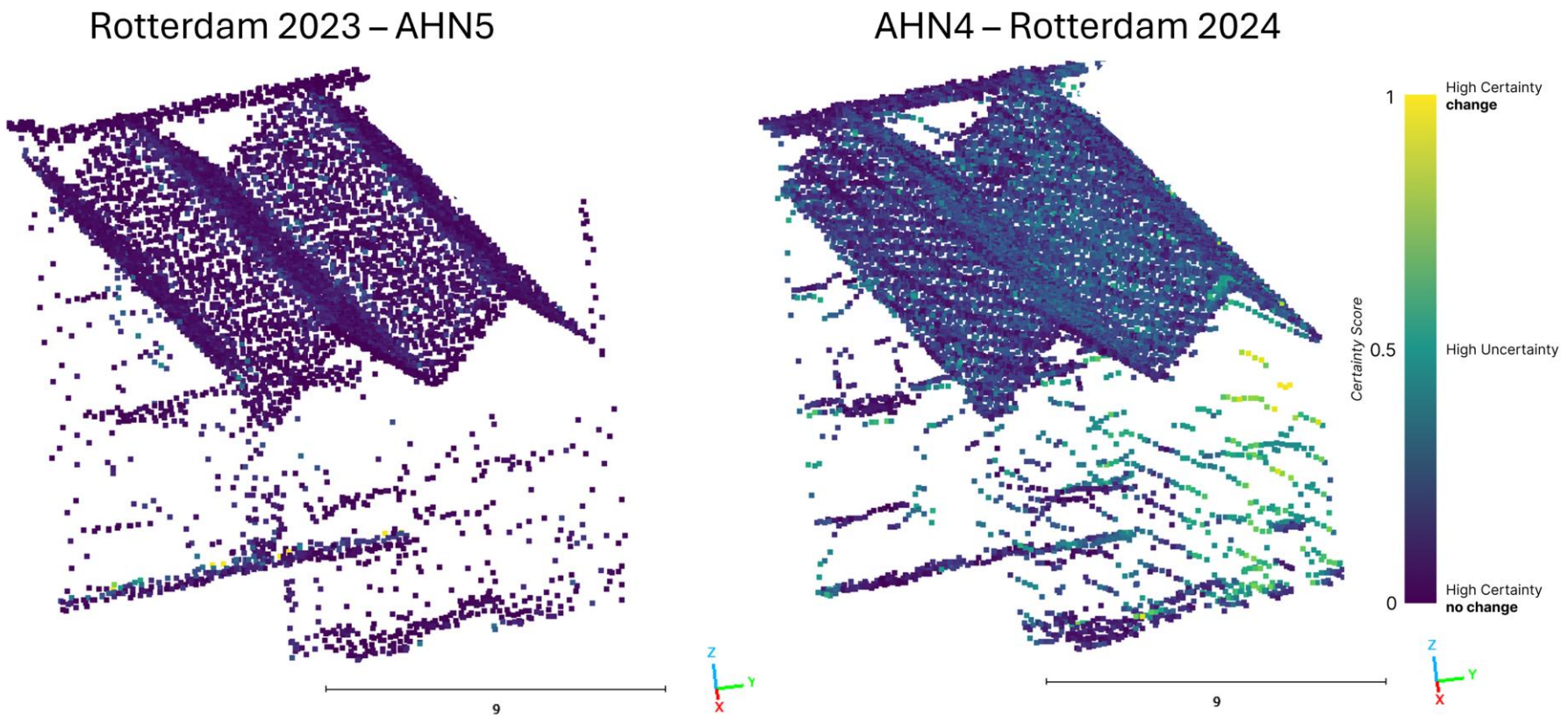

1
0.5
0
Certainty Score
High Certainty
change
High Uncertainty
High Certainty
no change
45
Z
Y
X

Extra slide

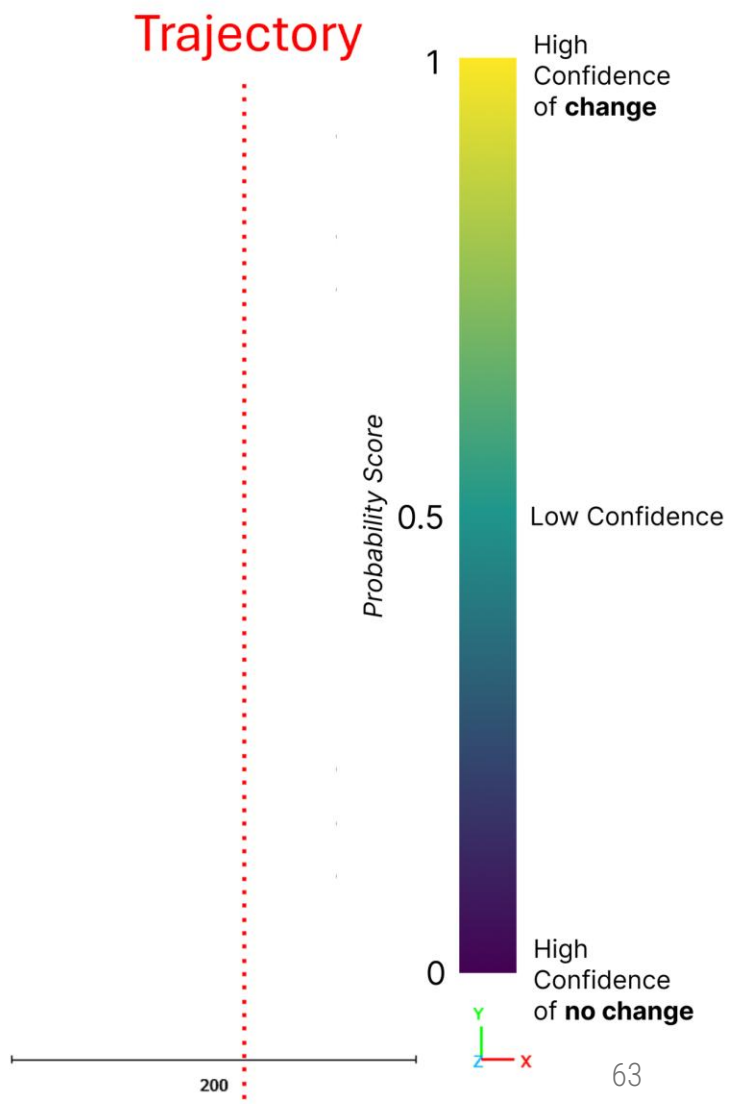

1
High Certainty
change
Certainty Score
0.5
High Uncertainty
0
High Certainty
no change
30
Z
X
Y

Extra slide

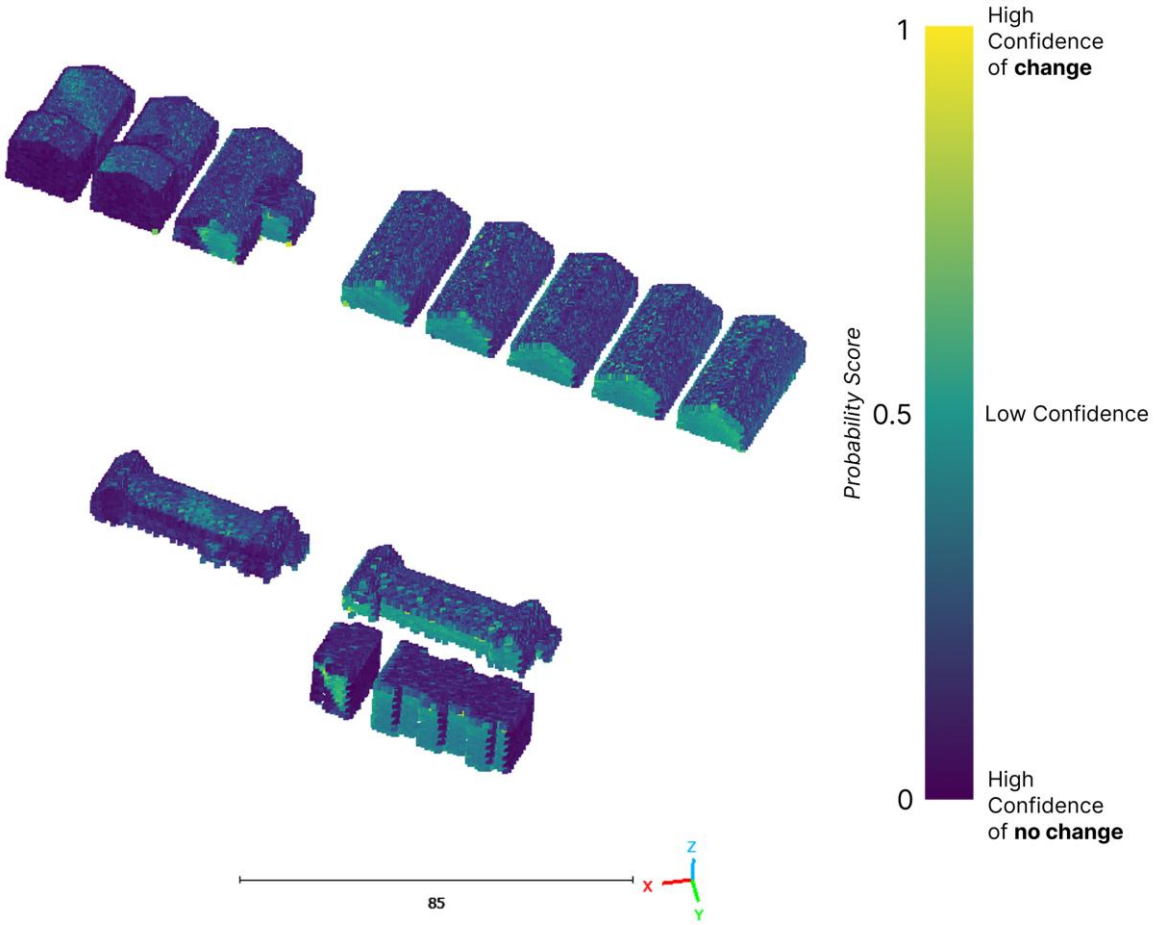

Rotterdam 2023 – AHN5
AHN4 – Rotterdam 2024
High Certainty
change
1
Certainty Score
0.5
High Uncertainty
0
High Certainty
no change
9
9
Z
Y
X
Z
Y
X

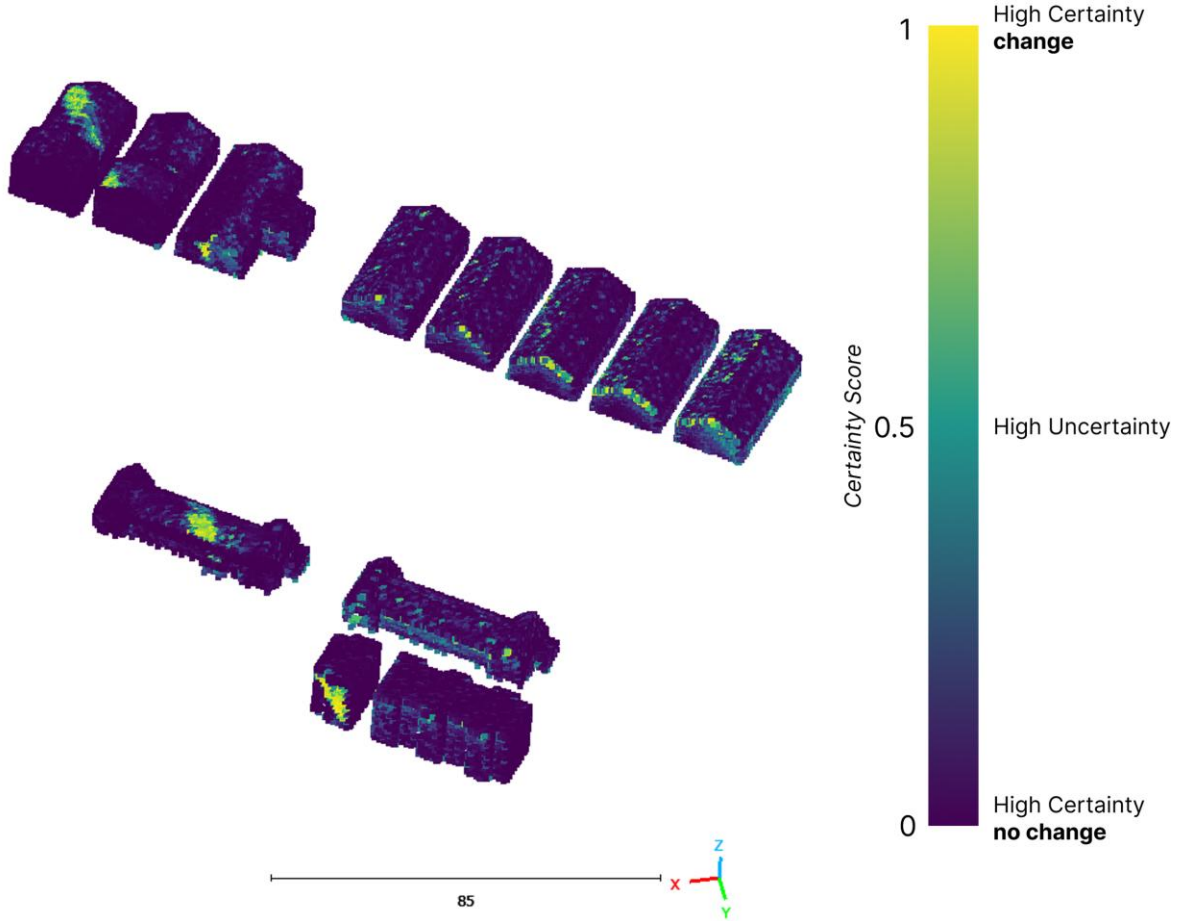
Extra slide

Trajectory
Adding SP12
Adding SP08
Adding SP04
Adding dormers

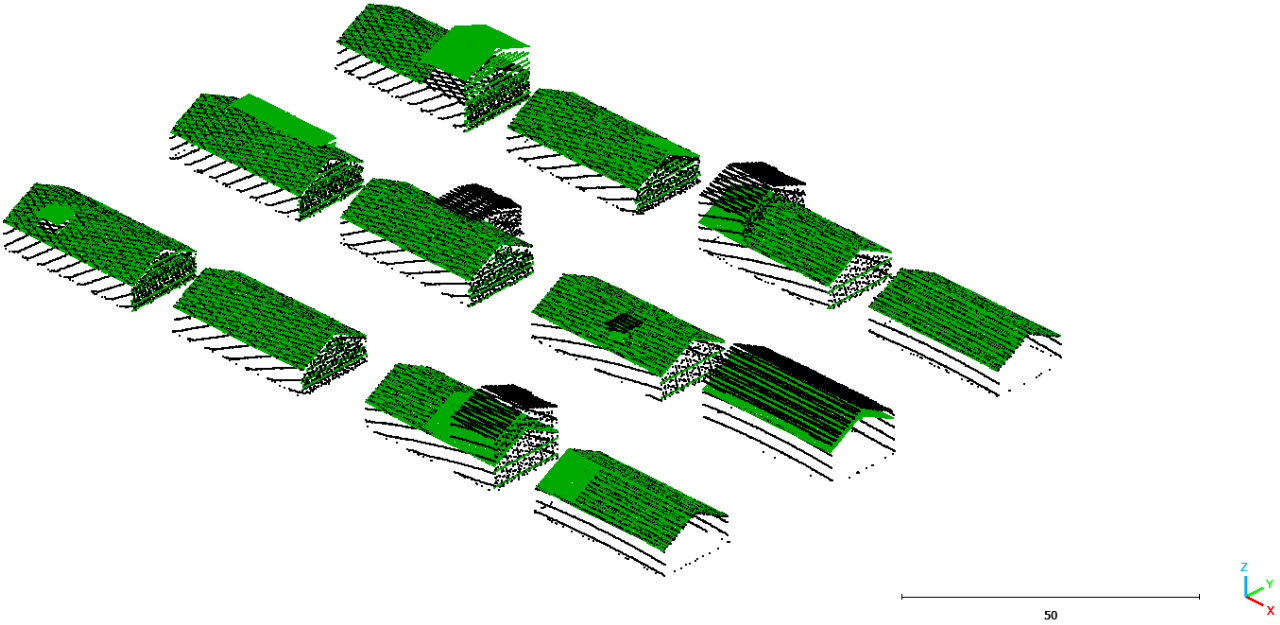

Trajectory
1
0.5
0
Probability Score
High Confidence of change
Low Confidence
High Confidence of no change
200

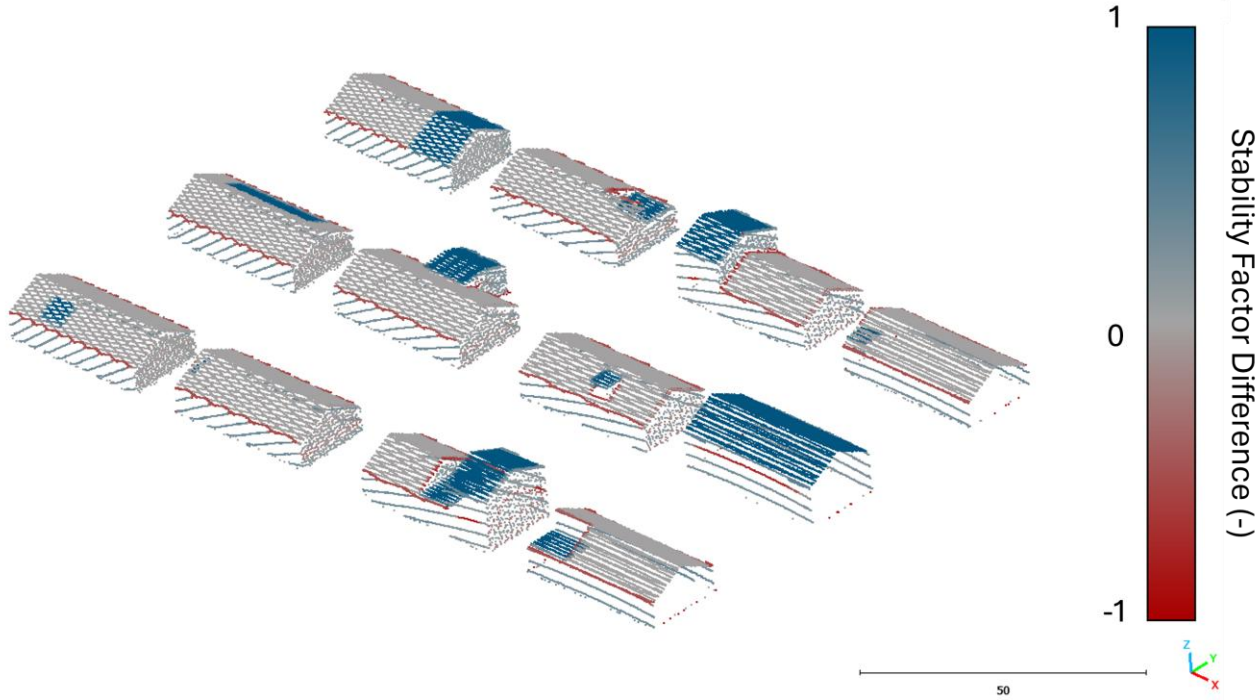
Extra slide


1
0.5
0
Probability Score
High Confidence of **change**
Low Confidence
High Confidence of **no change**
85
X
Z
Y


1
0.5
0
Certainty Score
High Certainty **change**
High Uncertainty
High Certainty **no change**
85
X
Z
Y

Extra slide





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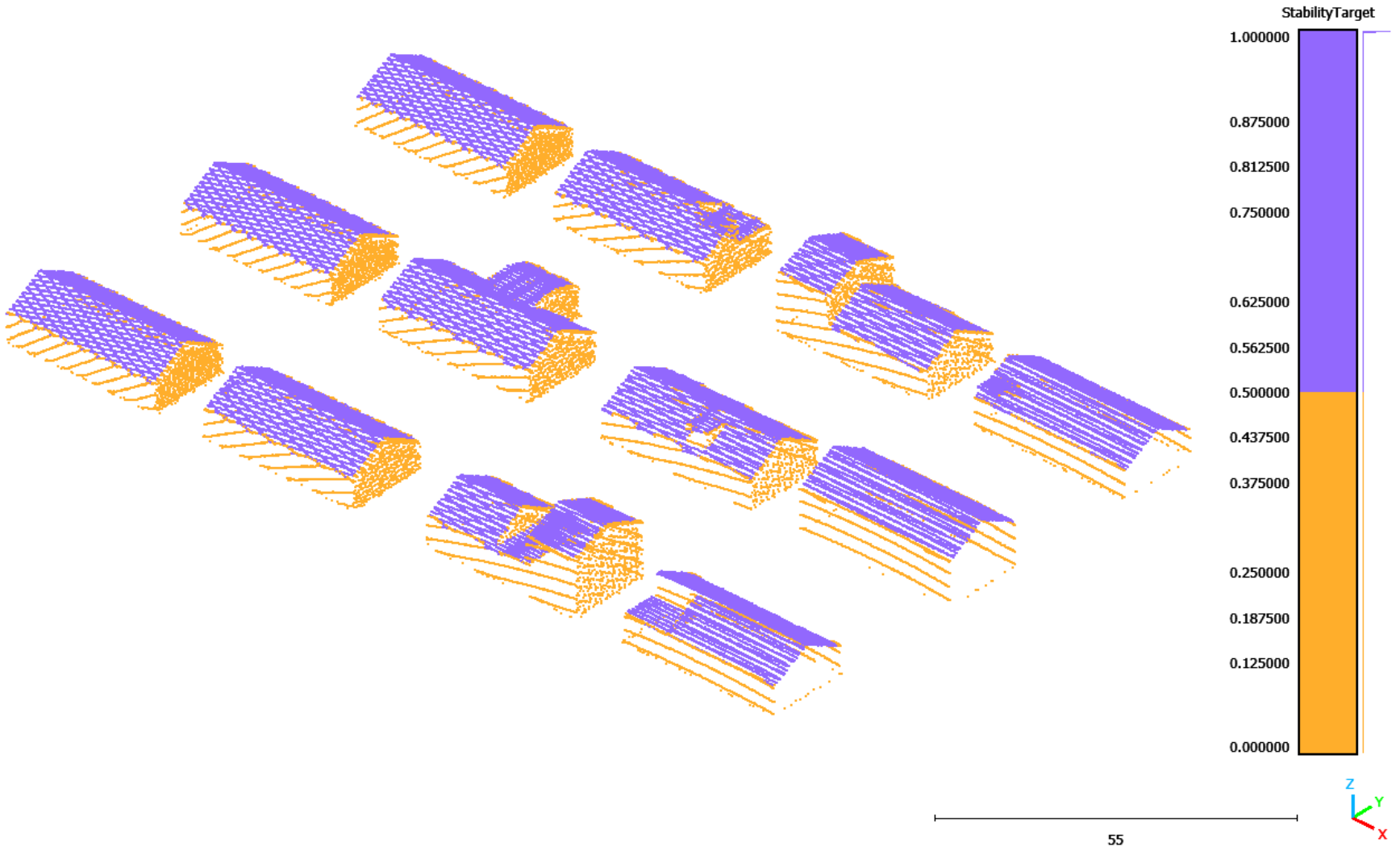
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0.812500
0.750000
0.625000
0.562500
0.500000
0.437500
0.375000
0.250000
0.187500
0.125000
0.000000
55
Z
Y
X