National Technical University Of Athens
School of Rural and Surveying Engineering

AUTOMATIC 3D RECONSTRUCTION OF BUILDINGS ROOF TOPS IN DENSELY URBANIZED AREAS

Maria Gkeli, Surveying Engineer, PhD student
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Introduction

❖ *Main Purpose:*

> *Automatic 3D reconstruction of buildings roof tops in densely urbanized areas, utilizing dense point clouds*
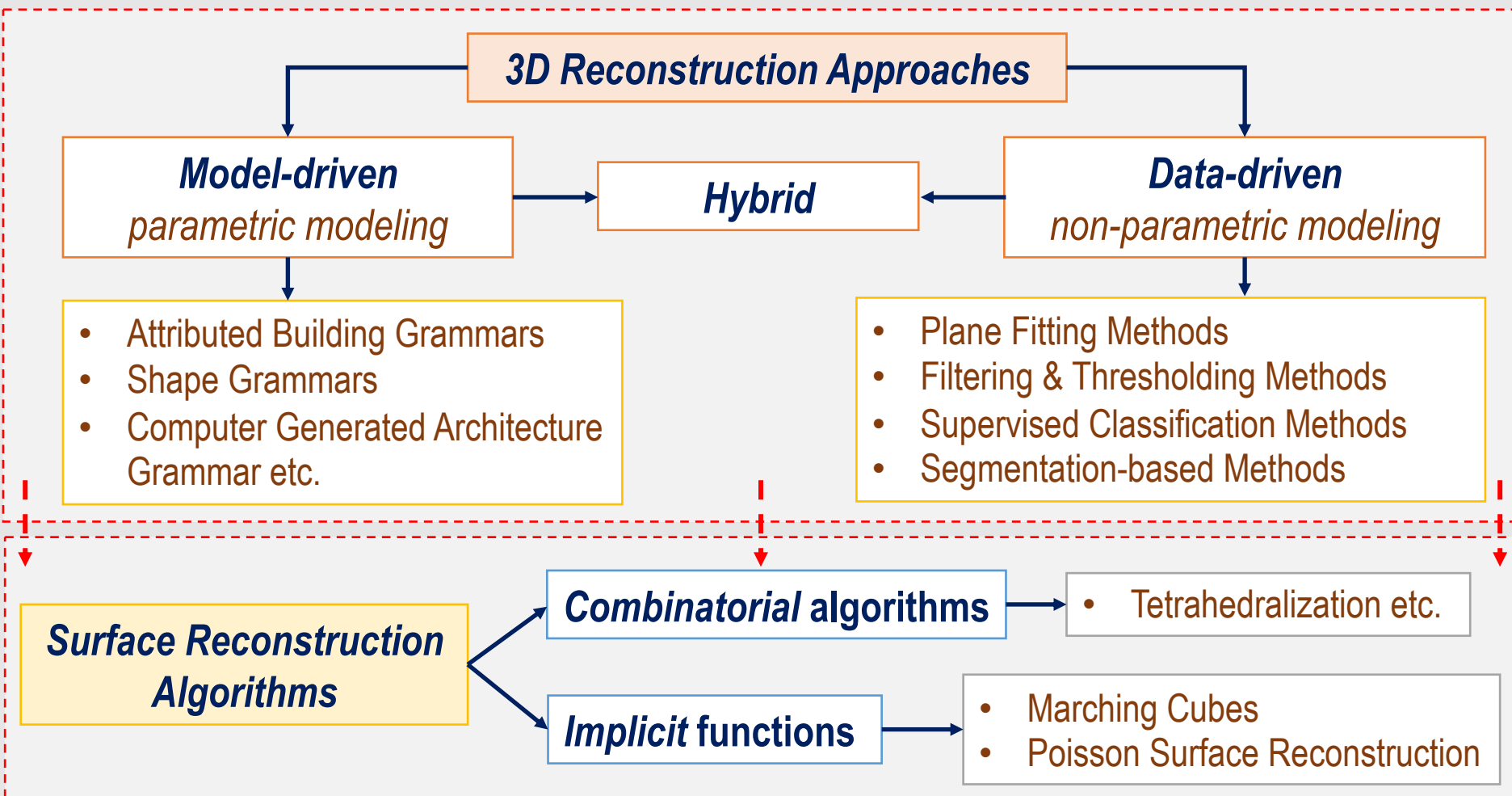
❖ **Current research trends:**

✓ automatic extraction and reconstruction of 3D buildings
✓ digital image matching as alternative to airborne LiDAR

❖ **Applications:**

✓ urban planning / 3D city modelling
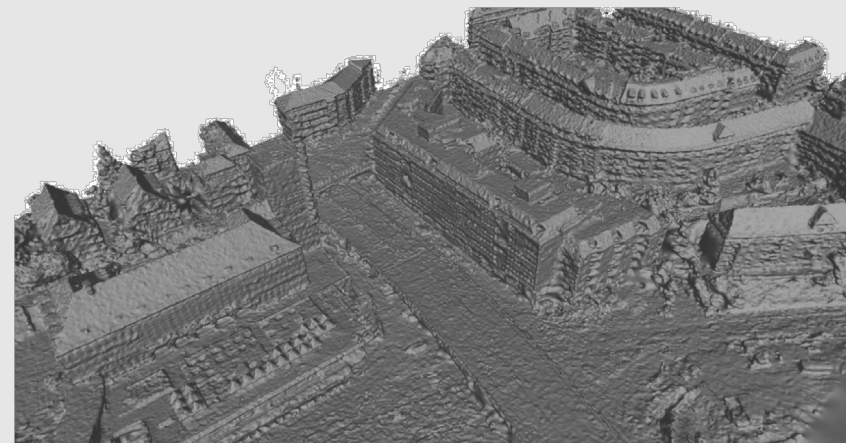✓ GIS
✓ tax assessment
✓ 2D/3D cadastre
✓ etc.

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3D Reconstruction

3D Reconstruction Approaches

Model-driven
parametric modeling

Hybrid

Data-driven
non-parametric modeling

- Attributed Building Grammars
- Shape Grammars
- Computer Generated Architecture Grammar etc.

- Plane Fitting Methods
- Filtering & Thresholding Methods
- Supervised Classification Methods
- Segmentation-based Methods

Surface Reconstruction Algorithms

Combinatorial algorithms

- Tetrahedralization etc.

Implicit functions

- Marching Cubes
- Poisson Surface Reconstruction

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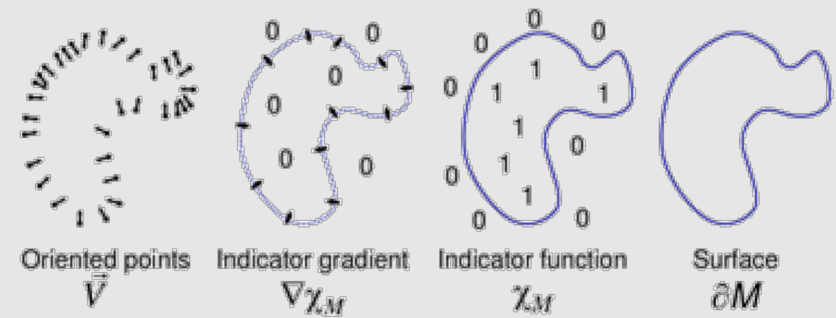
Poisson Surface Reconstruction Algorithm

✓ *Initial Data: Oriented point samples*

✓ *Main Phases:*
- *oriented point cloud → continuous vector field in 3D*
- *finding a scalar function whose gradients best match the vector field*
- *extraction of the appropriate Isosurface*

Oriented points $\vec{V}$ Indicator gradient $\nabla \chi_M$ Indicator function χ_M Surface ∂M

✓ *Advantages:*
- resilient to noise
- resilient to misregistration artifacts

✓ *Screened Poisson Surface Reconstruction*

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Proposed Methodology Overview

Phase 1
Outliers and non-roof elements are detected and removed

↓

Phase 2
Buildings roof tops geometry optimization

↓

Phase 3
Partial Surface reconstruction of buildings roof tops

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Partial Surface reconstruction of buildings roof tops
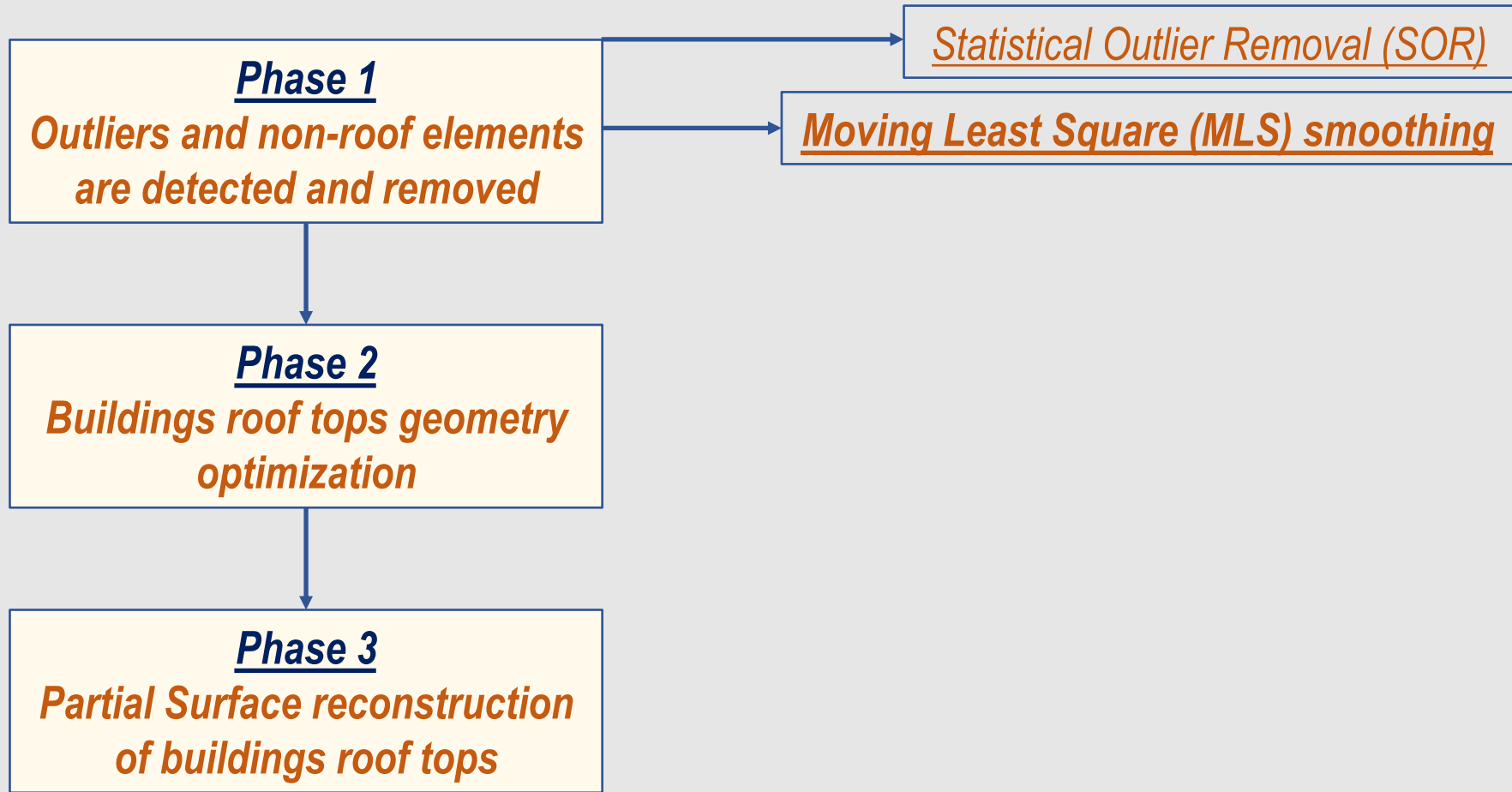
Statistical Outlier Removal (SOR)

$$P^* = \{p^*q \in P \mid (\mu k - \alpha \cdot \sigma k) \leq d^* \leq (\mu k + \alpha \cdot \sigma k) \}$$

where
- P = initial point cloud
- P^* = filtered point cloud
- μk = mean deviation
- σk = standard deviation
- α = desired density restrictiveness factor
- d = mean distance

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Proposed Methodology Overview

Phase 1
Outliers and non-roof elements are detected and removed

Statistical Outlier Removal (SOR)

Moving Least Square (MLS) smoothing

Phase 2
Buildings roof tops geometry optimization

Phase 3
Partial Surface reconstruction of buildings roof tops

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Proposed Methodology Overview

Phase 1
Outliers and non-roof elements are detected and removed

Statistical Outlier Removal (SOR)

Moving Least Square (MLS) smoothing

Detection and Removal of non-roof objects

Algorithmic process

Bottoms-Up Segmentation of P per 3m $q\ \{q_1..q_n\}$

Euclidean distance clustering $e\ \{e_1..e_n\}\ \epsilon\ q$ *(tolerance 1m)*

RANSAC plane fitting *for each e (threshold 0.5m)*

Moments of Inertia Calculation - **OBB** *(ratio$_{OBB}$ < 4)*

Thresholds check

Area Calculation *(area ≥ 10m^2)*

Phase 2
Buildings roof tops geometry optimization

Phase 3
Partial Surface reconstruction of buildings roof tops

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Proposed Methodology Overview

Phase 1
Outliers and non-roof elements are detected and removed
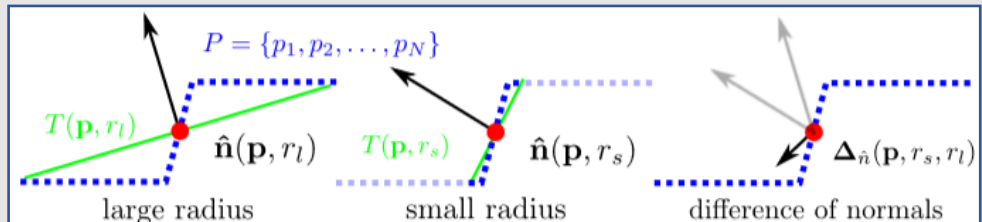
Phase 2
Buildings roof tops geometry optimization

Phase 3
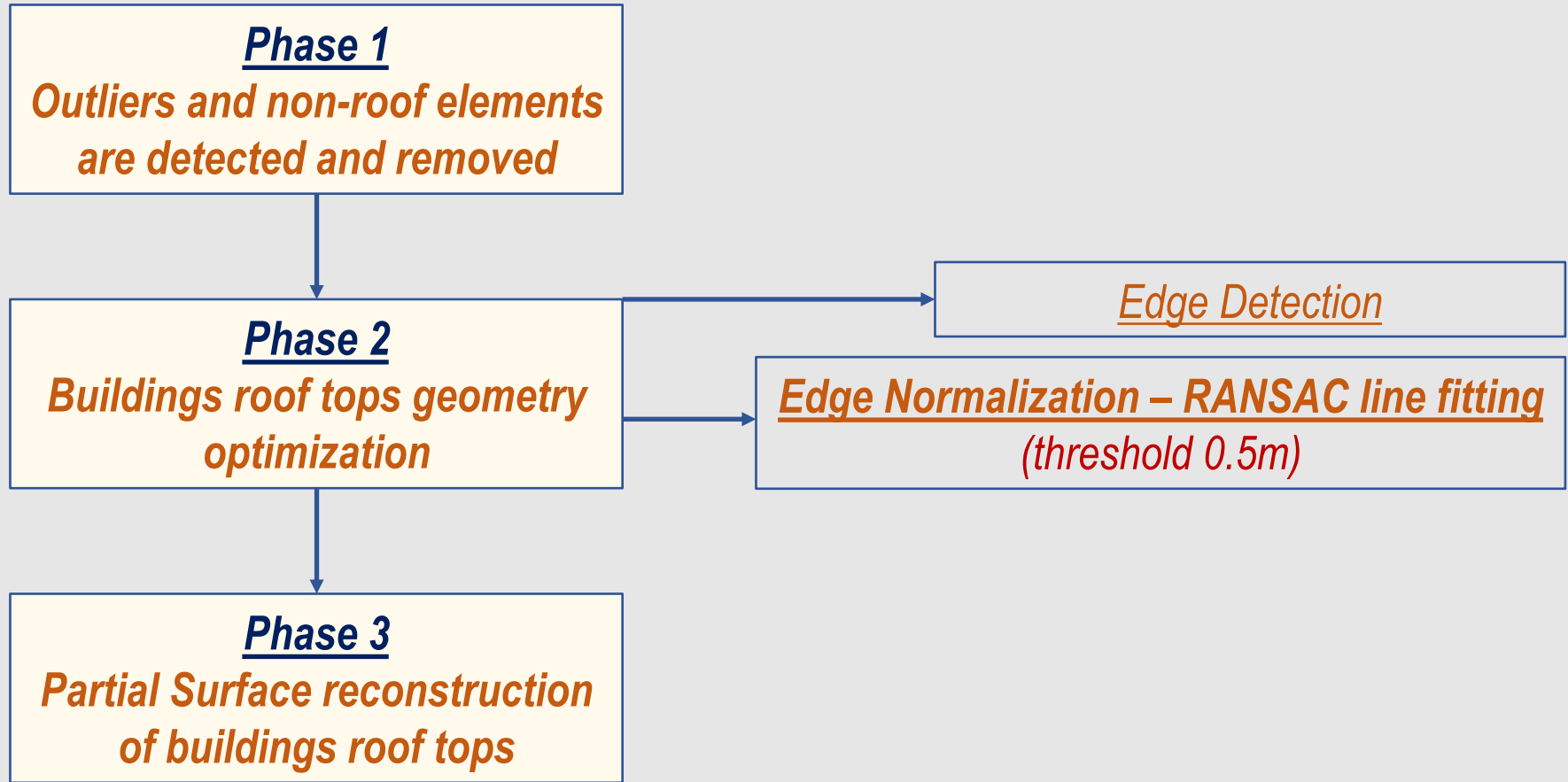*Partial Surface reconstruction of buildings roof tops*

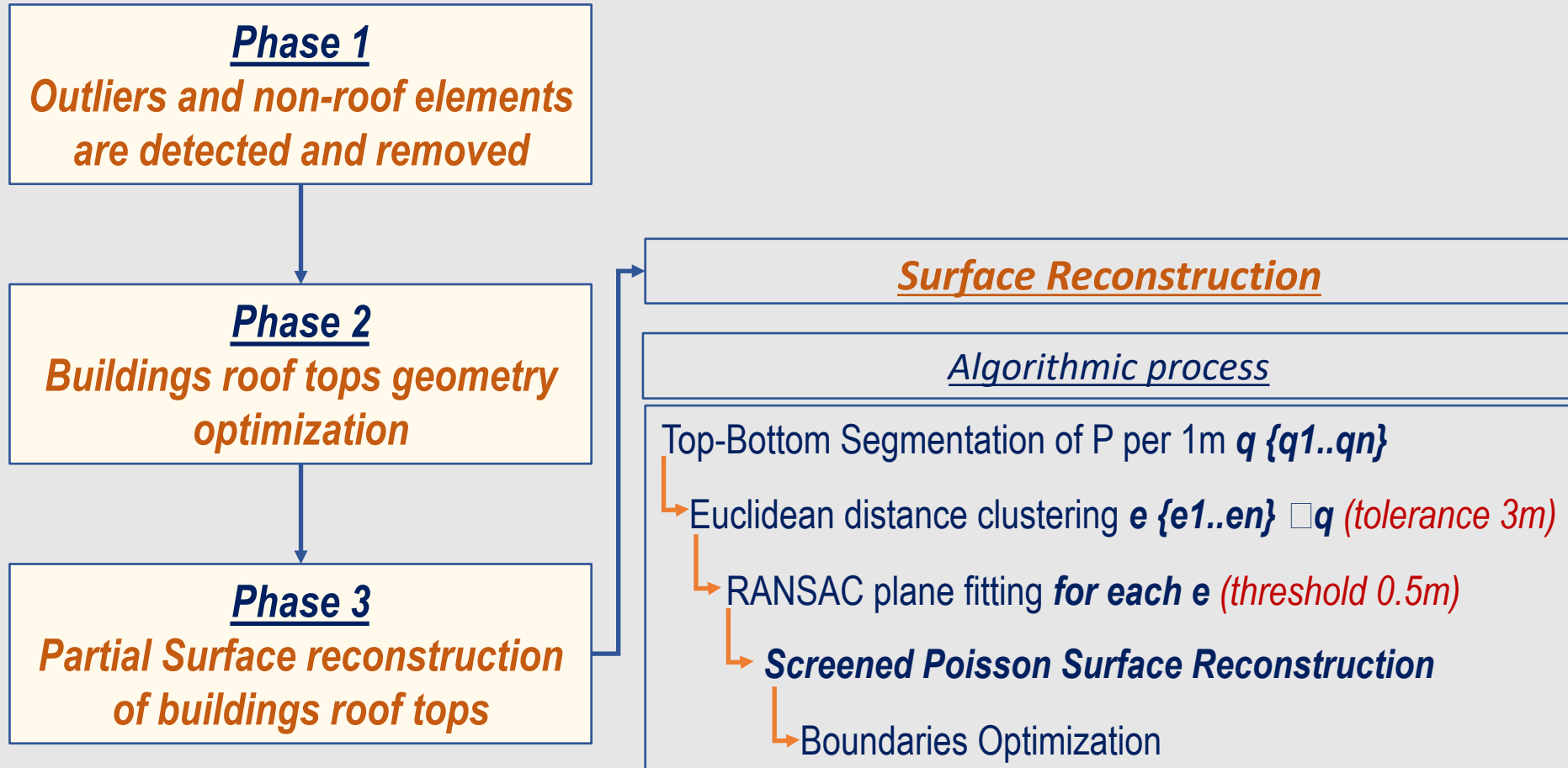**Edge Detection**

Differences of Normals (DoN)

$P = \{p_1, p_2, \ldots, p_N\}$

$T(\mathbf{p}, r_l)$ $\hat{\mathbf{n}}(\mathbf{p}, r_l)$

large radius

$T(\mathbf{p}, r_s)$ $\hat{\mathbf{n}}(\mathbf{p}, r_s)$

small radius

$\Delta_{\hat{n}}(\mathbf{p}, r_s, r_l)$

difference of normals

*Threshold value   **n≤0.80***

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Proposed Methodology Overview

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Phase 2
Buildings roof tops geometry optimization

Edge Detection

Edge Normalization – RANSAC line fitting
(threshold 0.5m)

Phase 3
Partial Surface reconstruction of buildings roof tops

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Proposed Methodology Overview

Phase 1
Outliers and non-roof elements are detected and removed

Phase 2
Buildings roof tops geometry optimization

Phase 3
Partial Surface reconstruction of buildings roof tops

Surface Reconstruction

Algorithmic process

Top-Bottom Segmentation of P per 1m *q {q1..qn}*

Euclidean distance clustering *e {e1..en}*   *q* *(tolerance 3m)*

RANSAC plane fitting *for each e* *(threshold 0.5m)*

Screened Poisson Surface Reconstruction

Boundaries Optimization

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Software Development

❖ *Main Objective*:

> *Automatic 3D Reconstruction of Buildings Roof Tops in Densely Urbanized Areas*

❖ *Input Data*: ASCII or Binary PCD (Point Cloud Data) file / coordinates X, Y, Z

❖ *Output Data*: VTK (Visualization Toolkit) file – reconstructed surface

❖ *Software tools*:

✓ Visual Studio 2013 – IDE
✓ Programming Language C++
✓ PCL - Point Cloud Library 1.8.0
✓ VTK - Visualization Toolkit
✓ Eigen Library

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Implementation (1/2)

❖ *Test Area*:
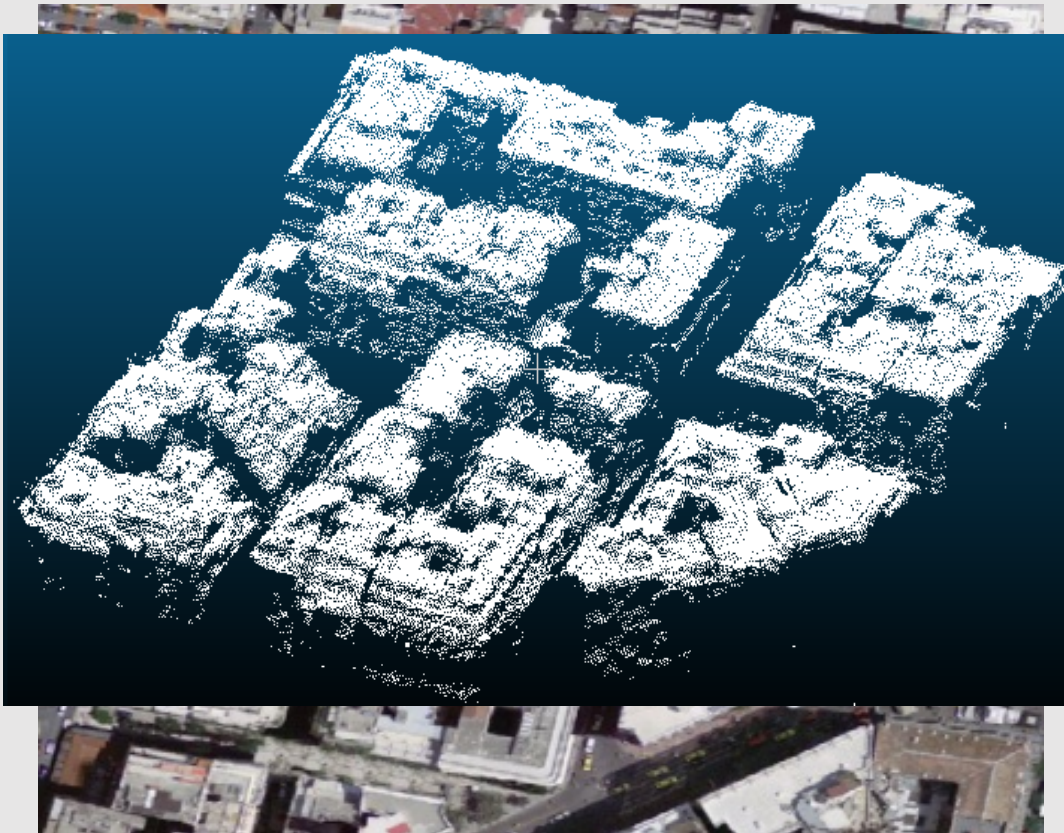
Special Characteristics:

✓ semi-detached buildings
✓ vague buildings boundaries
✓ varying heights
✓ non-smooth surfaces
✓ complex geometry
✓ existence of several non-structural objects (noise)

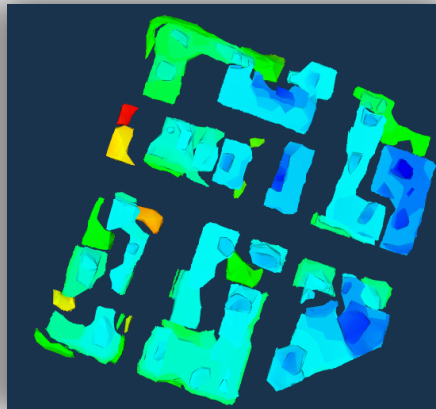Gkeli, M., & Ioannidis, C., 2018. Automatic 3D Reconstruction of Buildings Roof Tops in Densely Urbanized Areas. In: *3D GeoInfo Conference*, 1-2 October 2018, Delft, the Netherlands

Implementation (2/2)

Segmentation per 3m
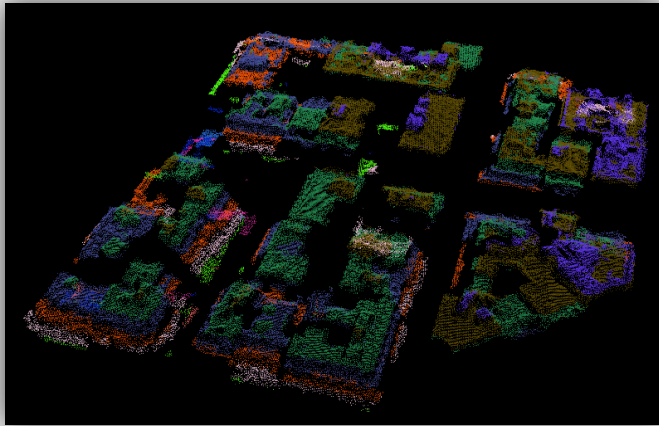
Detection and Removal of non-roof elements
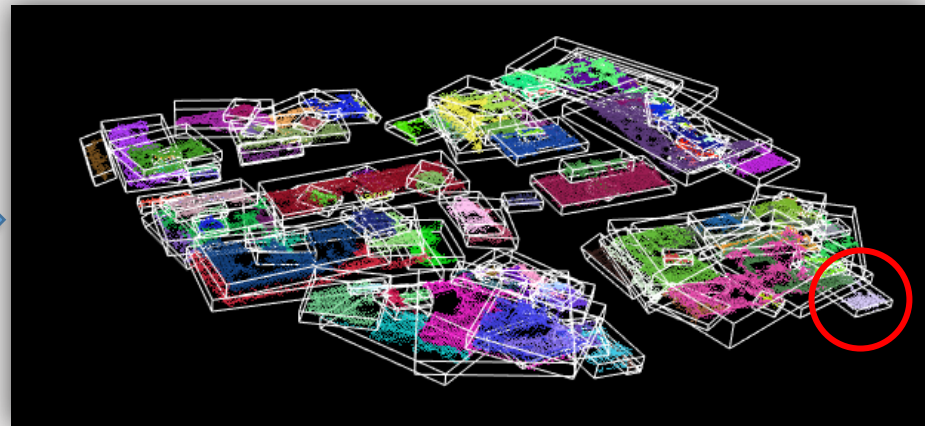
3D Reconstruction of Buildings Roof Tops

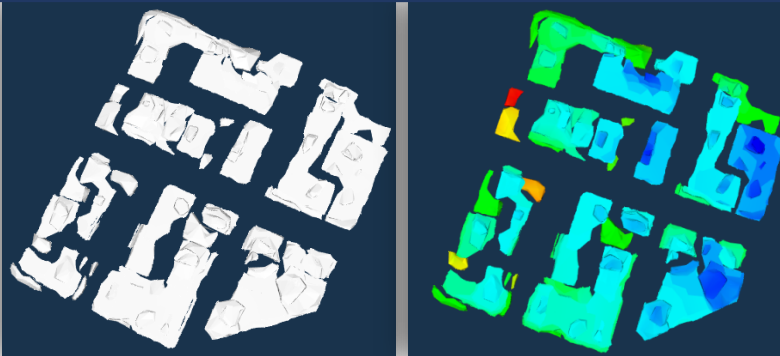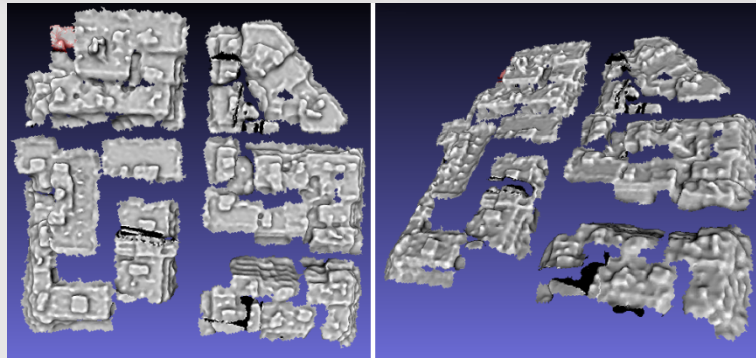## Edges Detection and Normalization

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Results Evaluation

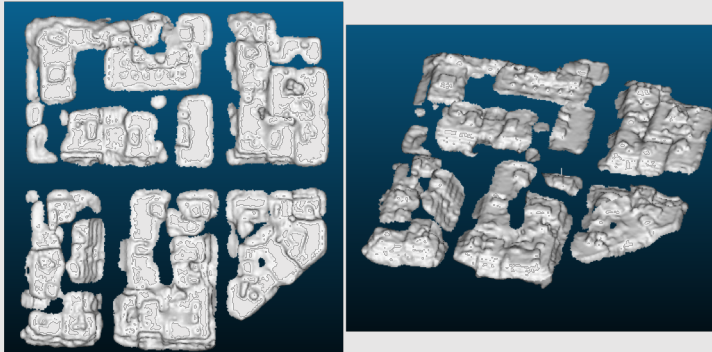|		
Proposed Methodology		
Screened Poisson reconstruction / **MeshLab**		
CloudCompare		

- ✓ Smooth surfaces
- ✓ Detection and removal of noise and non-roof elements
- ✓ Distinct edge definition - smooth / regular shape

- ✓ Noisy rough surfaces
- ✓ Remaining noise referring to non-roof elements
- ✓ Noisy edges / wavy segments
- ✓ Complex surfaces

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Thank you for your attention!

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