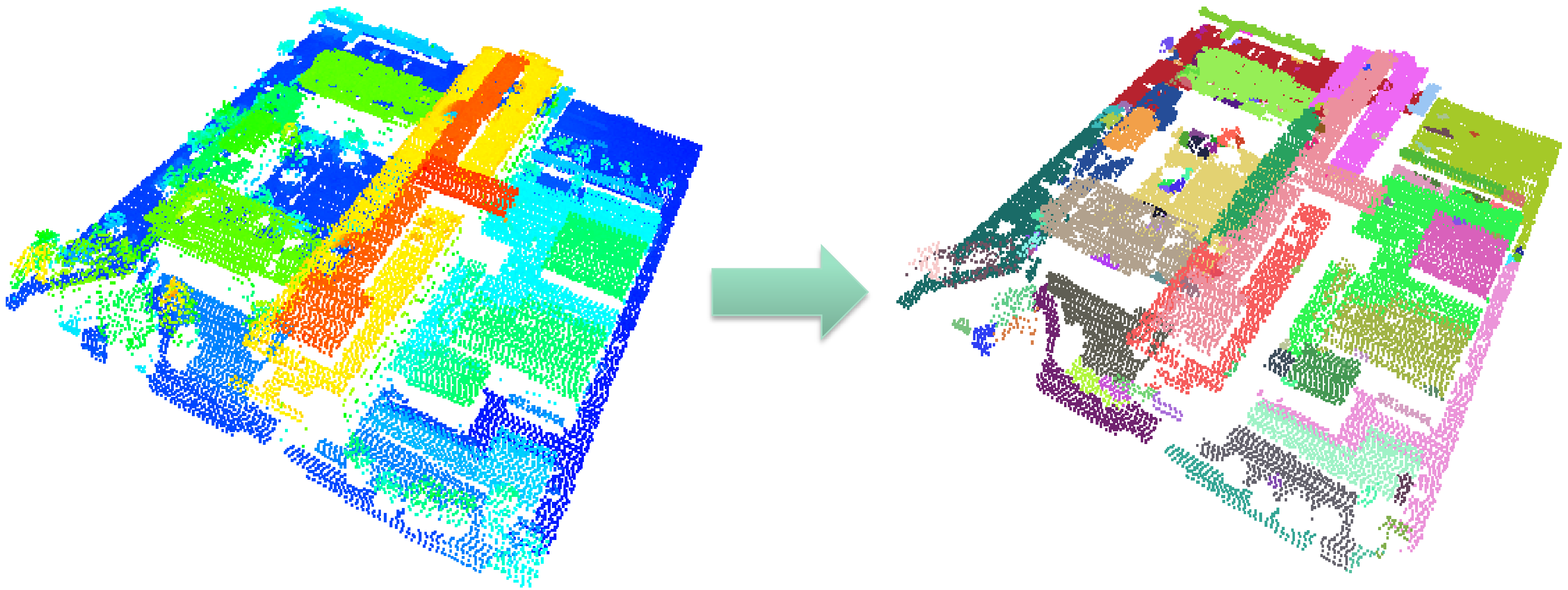
UAS-Based LiDAR Mapping

Video G-II

LiDAR Data Segmentation

LiDAR Data Segmentation

- **Segmentation Process: Abstraction of the LiDAR points into distinct regions whose constituents share similar attributes.**
  - Segmentation is usually considered as the prerequisite step for feature extraction and data interpretation.



Original point cloud **Segmented point cloud**

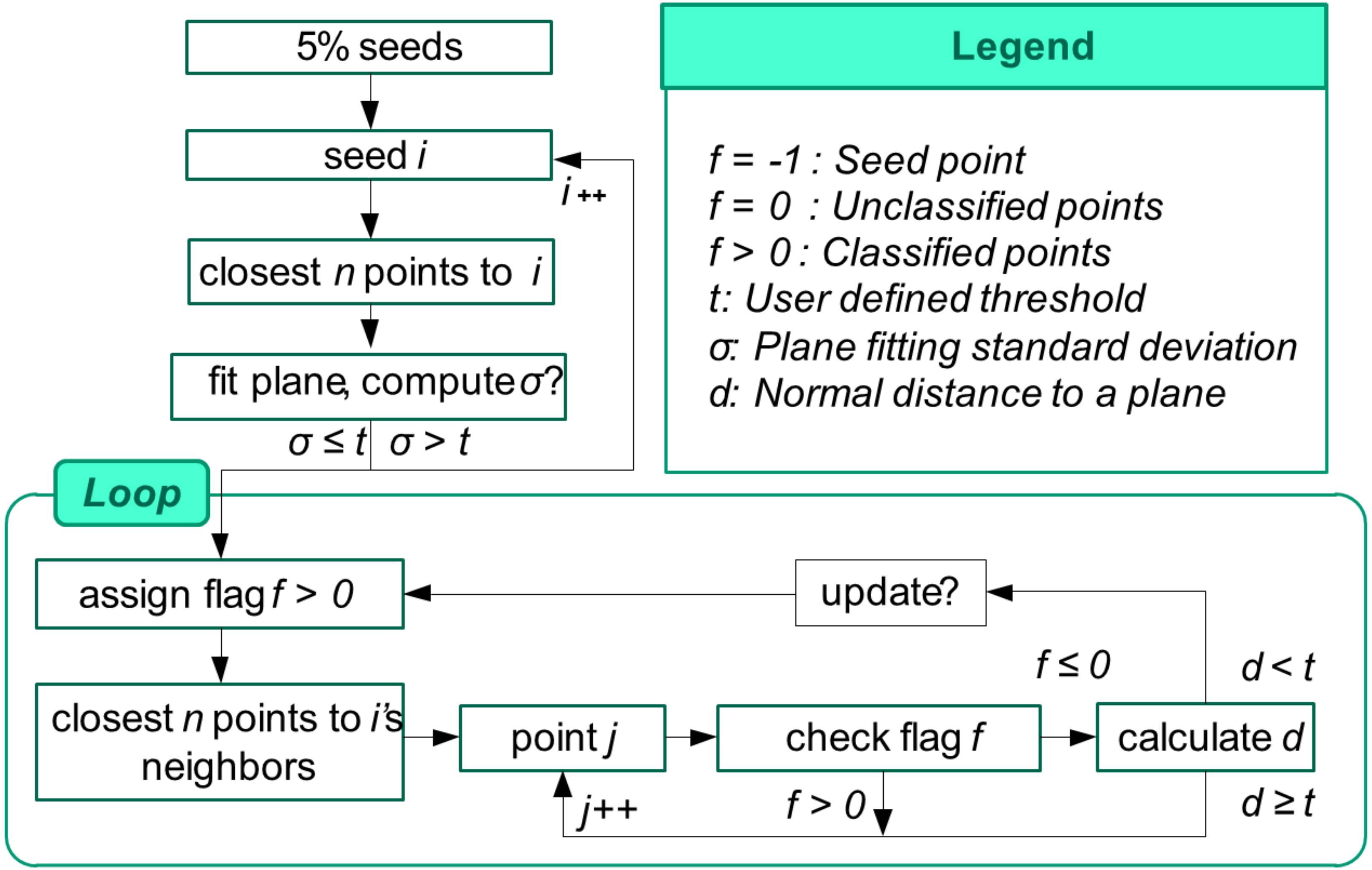
LiDAR Data Segmentation: Existing Approaches

I. **Spatial-domain techniques** segment the point cloud based on the proximity of points and similarity of locally estimated attributes.
   - Dependency of the majority of these approaches on the selection of seed points
   - Sensitivity to noisy data
   - Non-optimal segmentation around edges where two surfaces meet

II. **Parameter-domain techniques** aggregate points with similar attributes into clusters in an attribute space.
   - Lack of computational efficiency when dealing with multidimensional attributes for a massive amount of points
   - Not considering the connectivity of the points in the object domain

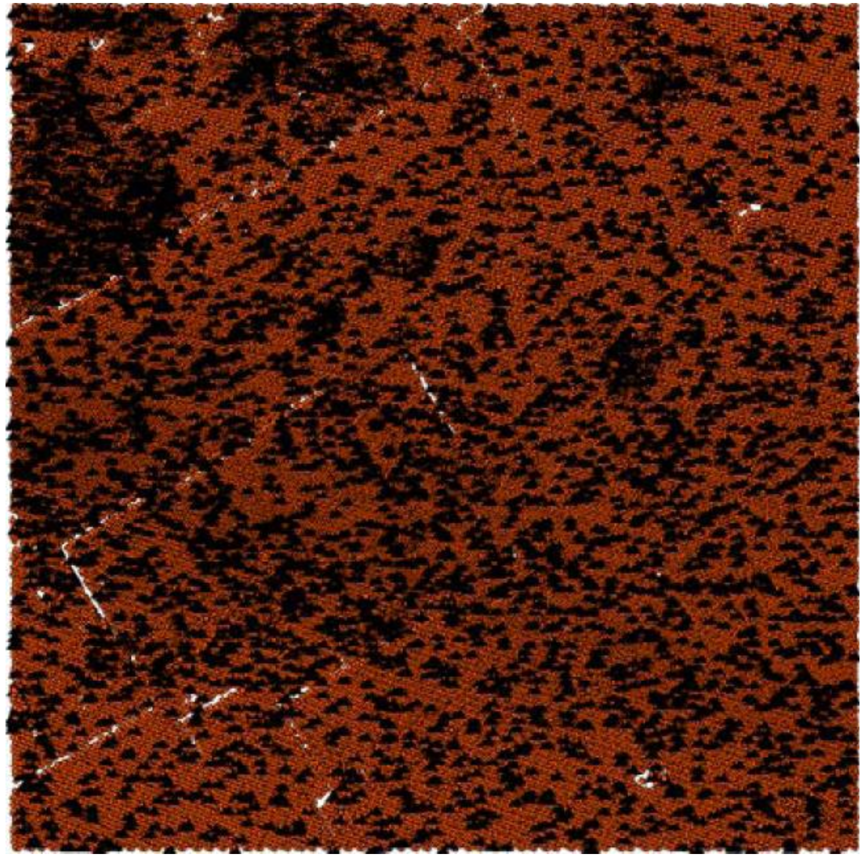
Spatial-Domain Segmentation

Single Scan Segmentation



Spatial-Domain Segmentation

Single Scan Segmentation

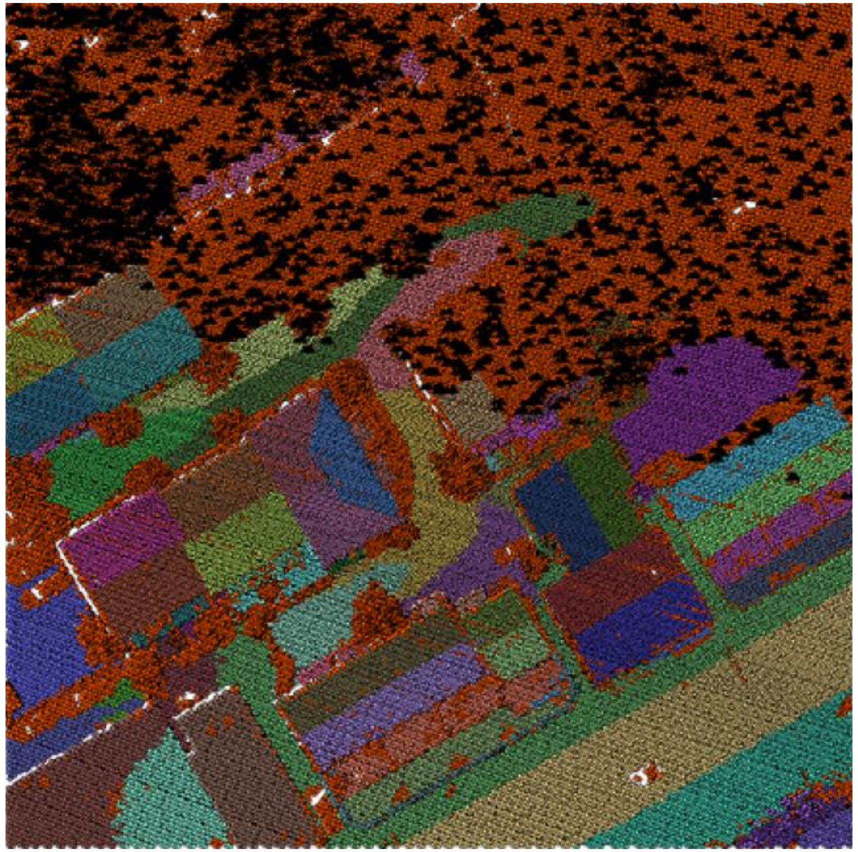


A subset of collected airborne LiDAR points, where 5% of the points are randomly selected as seeds (dark points) for the region growing purposes

PURDUE UNIVERSITY

Spatial-Domain Segmentation

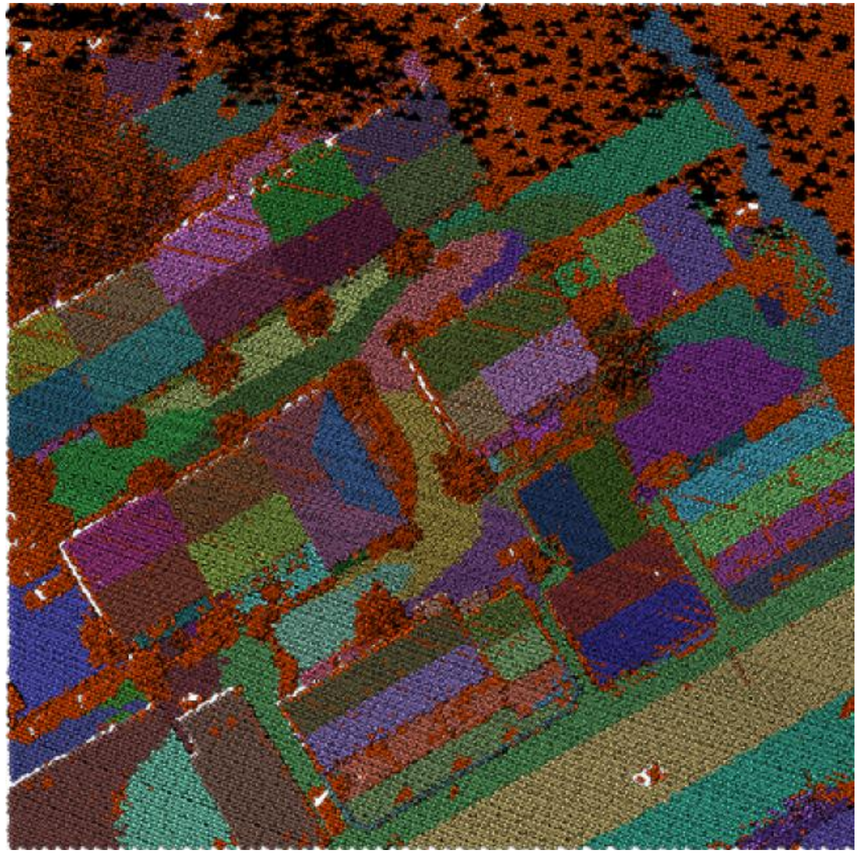
Single Scan Segmentation



The progress of the segmentation after processing 65% of the data points

Spatial-Domain Segmentation

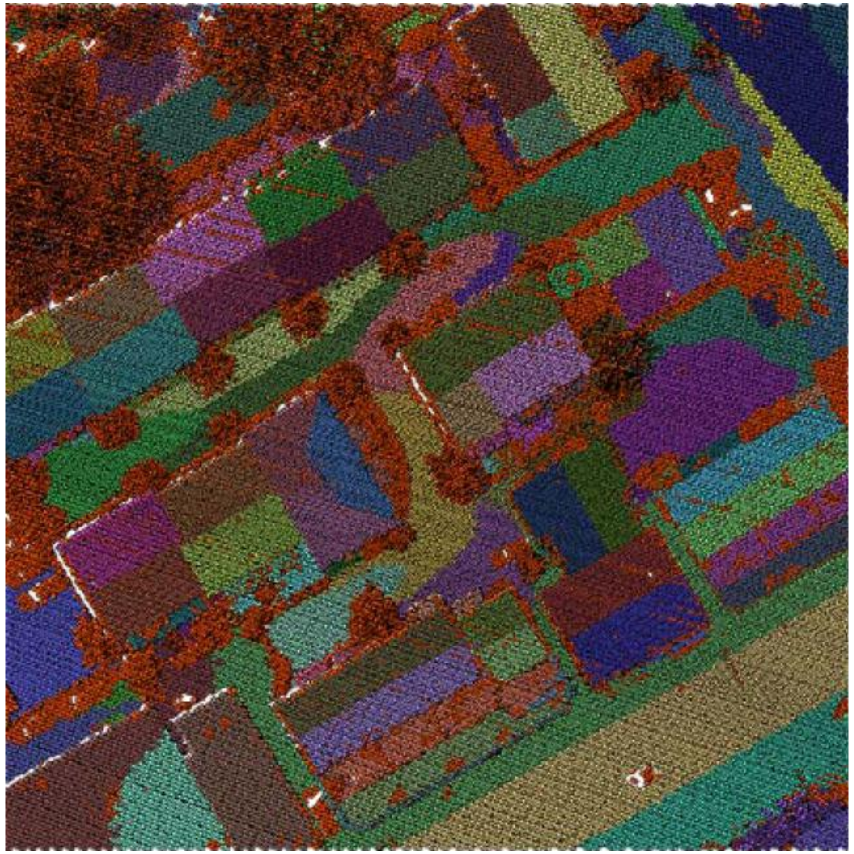
Single Scan Segmentation



The progress of the segmentation after processing 85% of the data points

Spatial-Domain Segmentation

Single Scan Segmentation

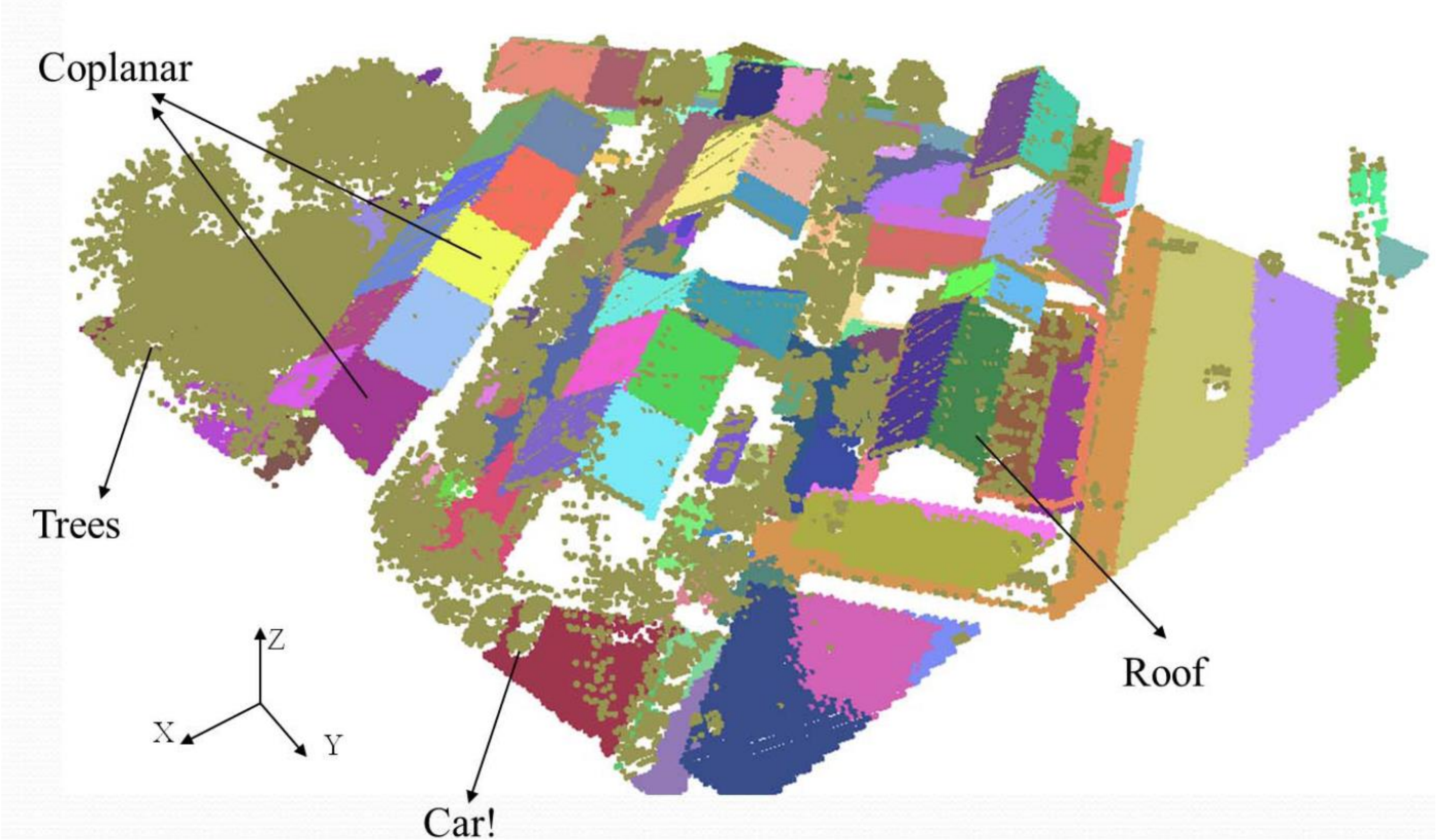


The progress of the segmentation after processing 100% of the data points (non-segmented points are shown in dark orange)

PURDUE UNIVERSITY

Spatial-Domain Segmentation

Single Scan Segmentation

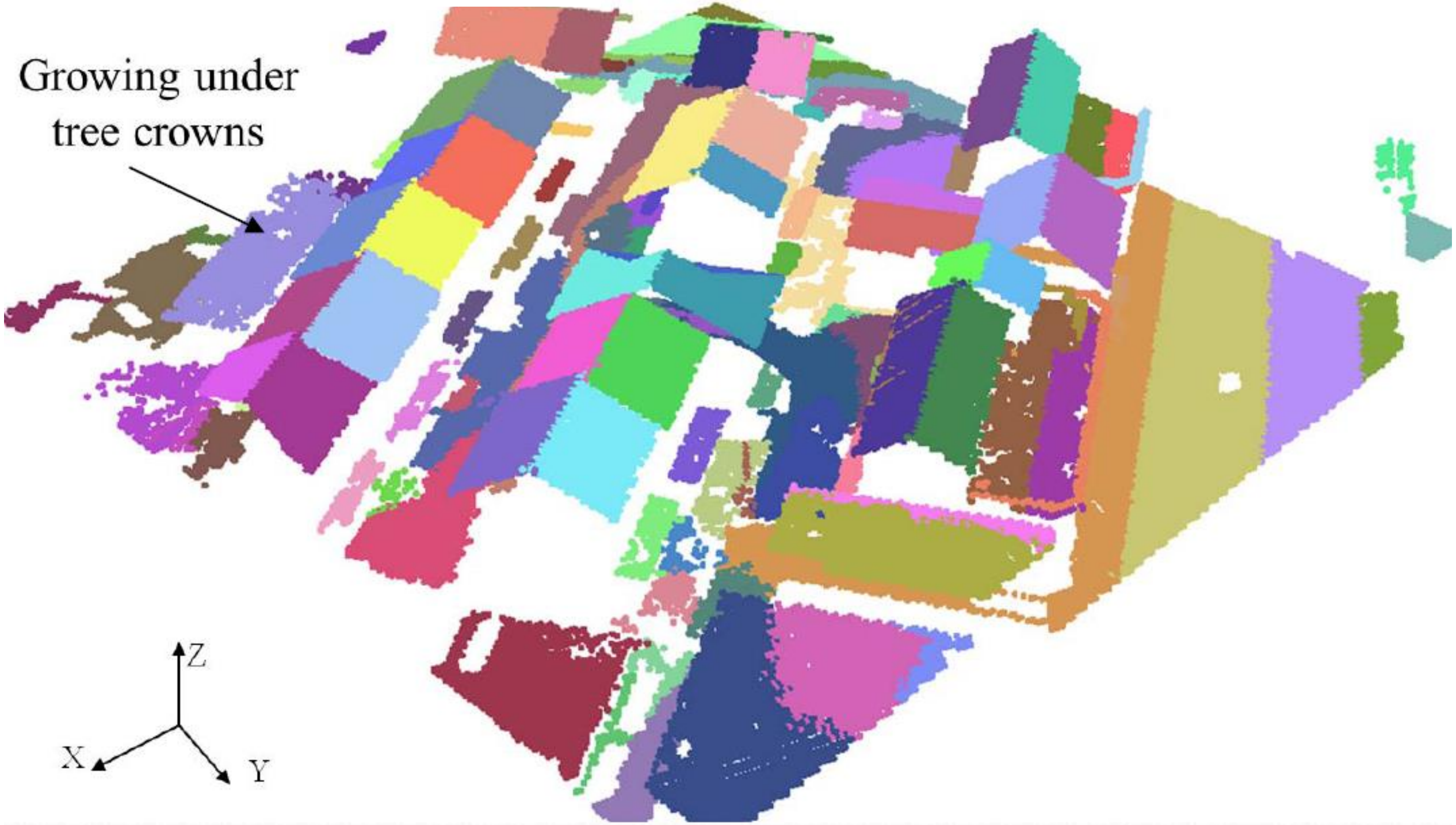


Segmentation results (including non-segmented points)

PURDUE UNIVERSITY

Spatial-Domain Segmentation

Single Scan Segmentation



Segmentation results (excluding non-segmented points)

Parameter-Domain Segmentation

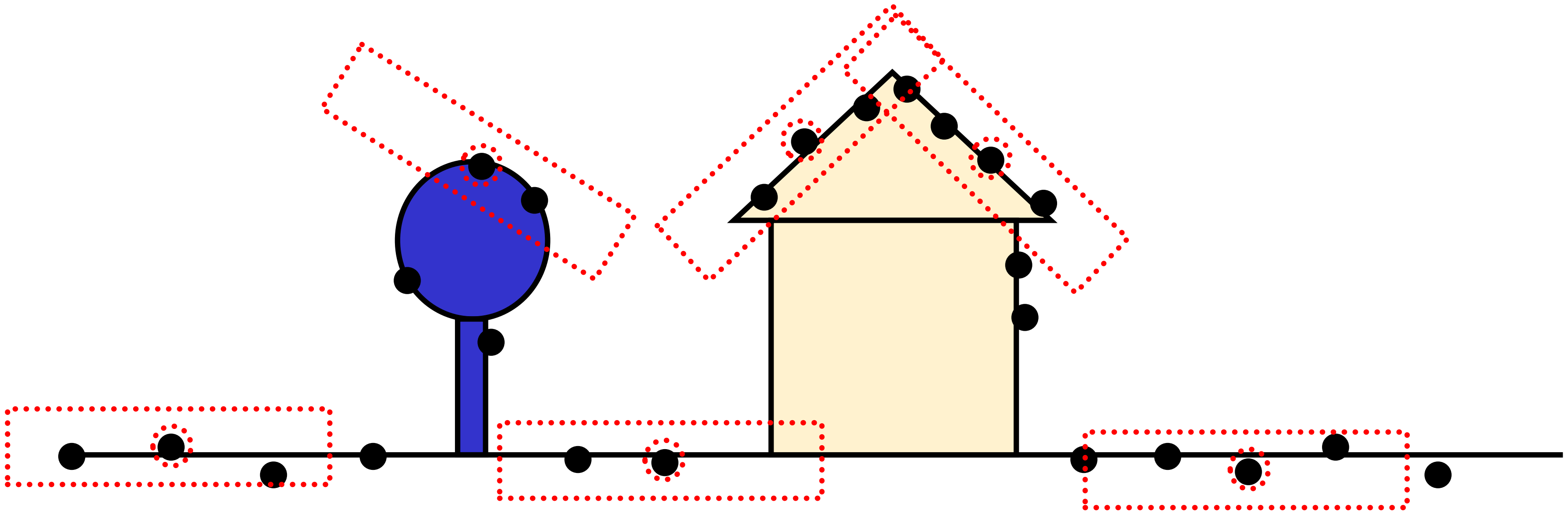
Parameter-Domain Segmentation

Parameter-domain segmentation

Neighborhood definition → LPD estimation → Attribute computation → Aggregation/ clustering → Boundary detection

Parameter-Domain Segmentation

- **Neighborhood Definition:** A rule that determines the neighbors of each point.
  - This definition significantly affects the validity of computed attributes for LiDAR point cloud segmentation.

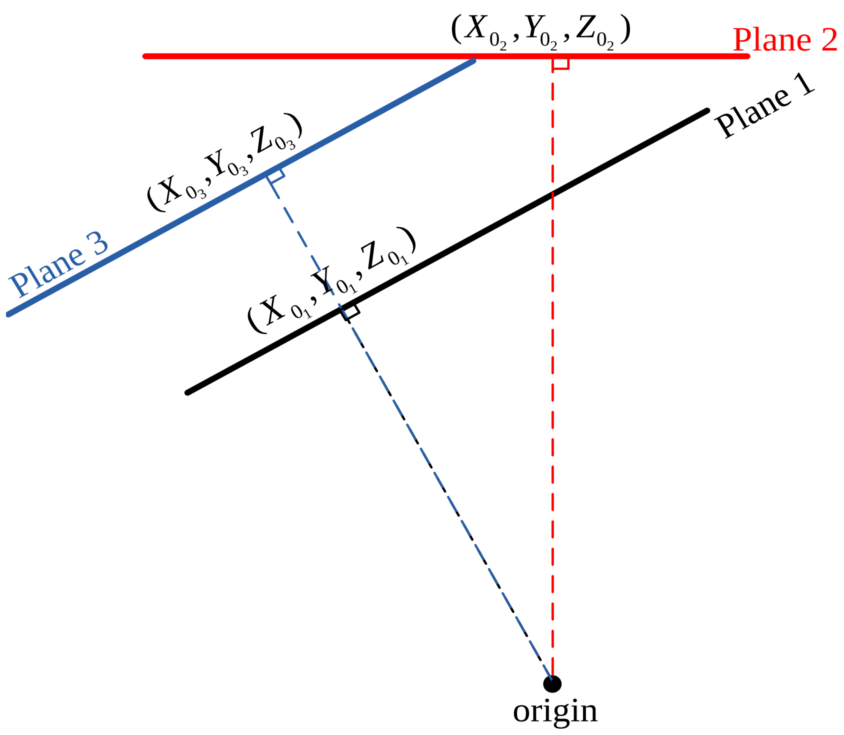


Neighborhood defined by adaptive cylinder

Parameter-Domain Segmentation

- **Attribute computation: Estimation of criteria which are used for measuring the similarity among a group of points in order to abstract the laser point cloud into distinct subsets of points**

- **Utilized attributes: the coordinates of origin's projection on the best fitting plane to each point's 3D neighborhood (X_0, Y_0, Z_0) derived through adaptive cylinder definition.**



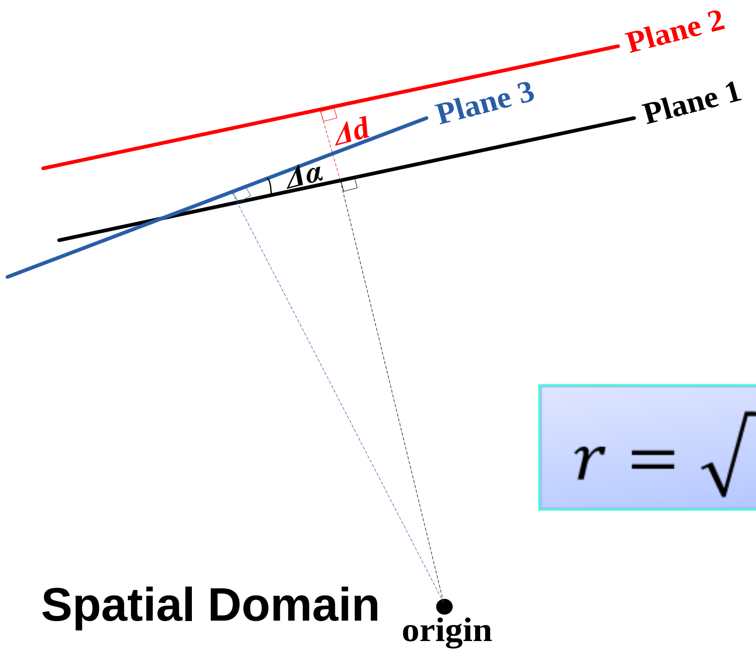
Clustering – Peak Detection

- **Usually, cluster detection is carried out using a tessellated accumulator array in the parameter/attribute space.**
  - The quality of the segmentation outcome depends on the cell size of the tessellation.
  - To avoid this problem, we introduce **two different methods** for peak detection in the attribute space:
    - Brute-force approach for peak detection
    - Fast approach for peak detection: An octree space partitioning for **coarse detection** followed by a **fine detection** of the peak.
- **For either method, we need to specify the expected spread of the cluster in the attribute space (acceptable spatial and angular deviation among the attributes of the points in a given cluster).**

Parameter-Domain Segmentation

- **Determination of expected cluster extent in attribute space**
  - The impact of $\Delta\alpha$ and Δd on the cluster extent:

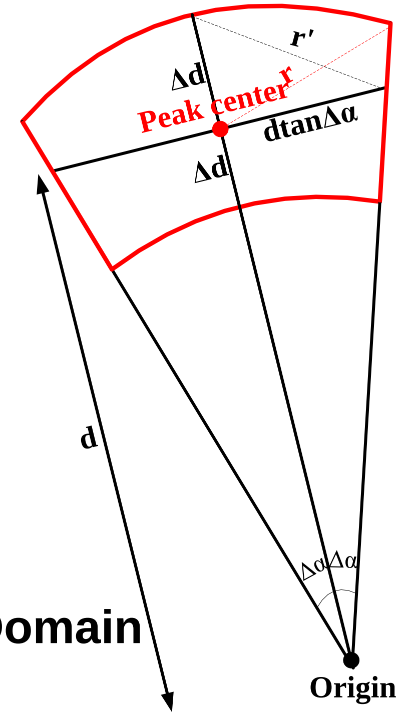
Δα	Acceptable angular deviation between two planes that should be clustered as one plane
Δd	Acceptable spatial separation between two parallel planes that should be clustered as one plane



Spatial Domain

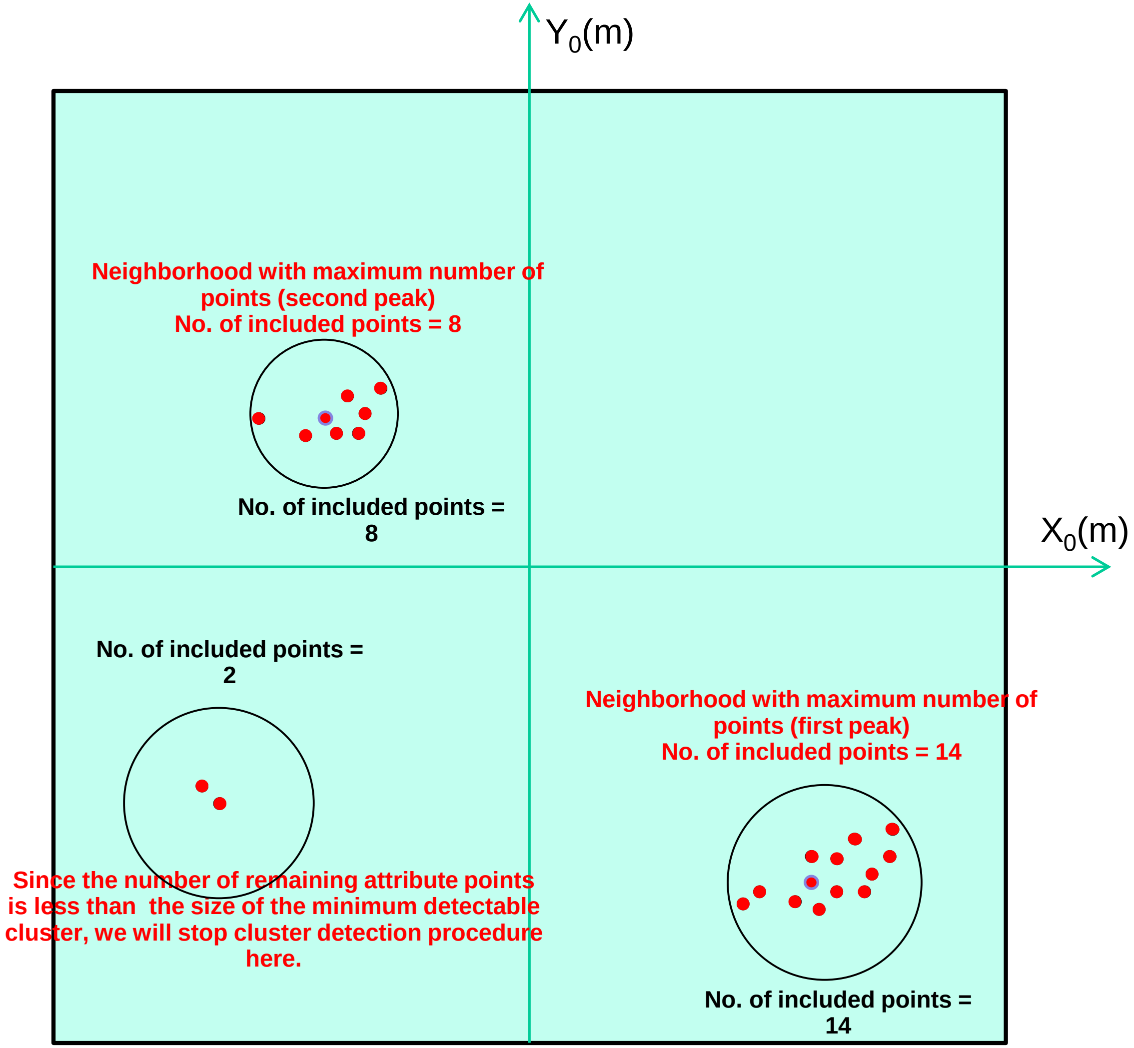
$$r = \sqrt{(dtan\,\Delta\alpha)^2 + (\Delta d)^2}$$

Parameter Domain



Parameter-Domain Segmentation

- **Brute-force Approach for Peak Detection:**

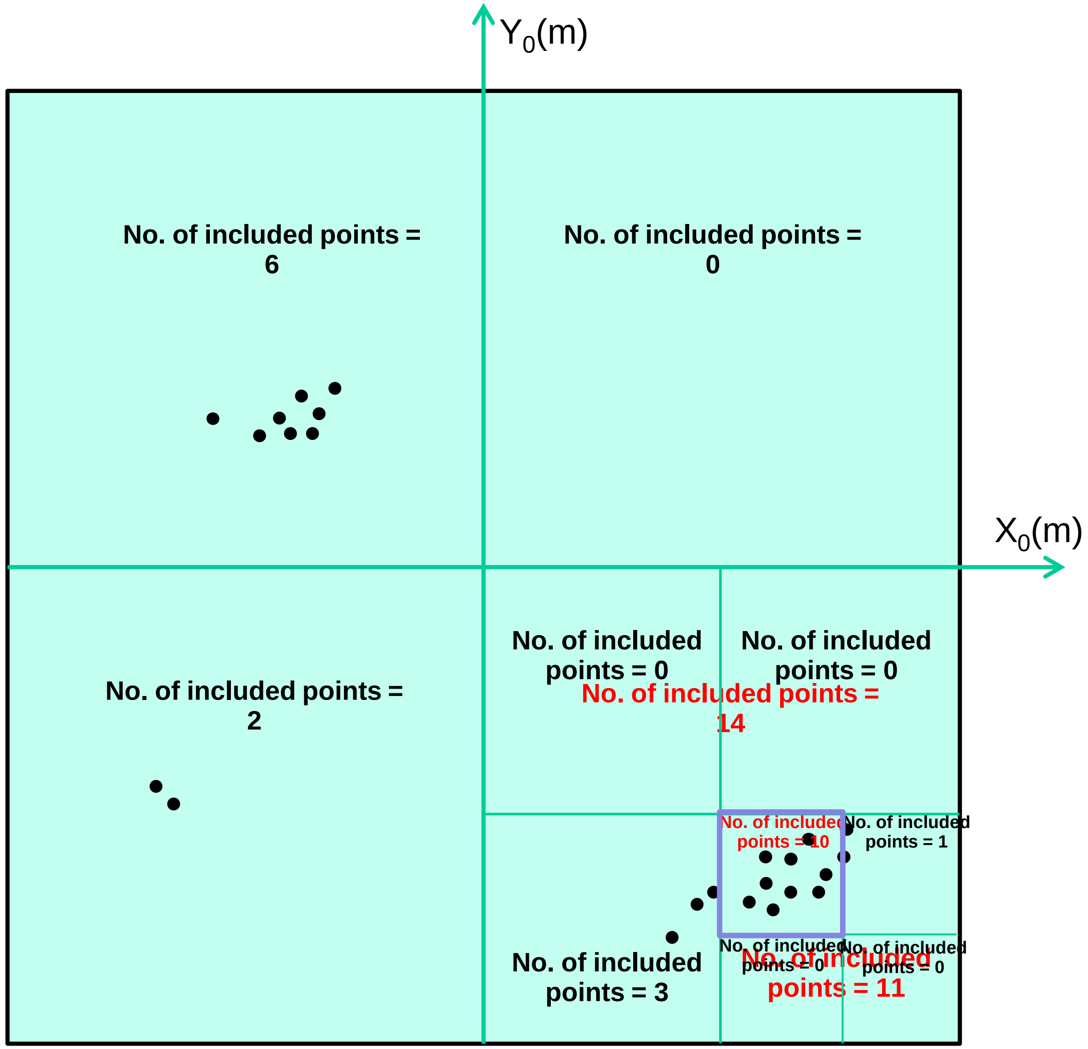


2D representation of brute-force peak detection approach

Note: The radius of the spherical neighborhood changes from one point to the next.

Parameter-Domain Segmentation

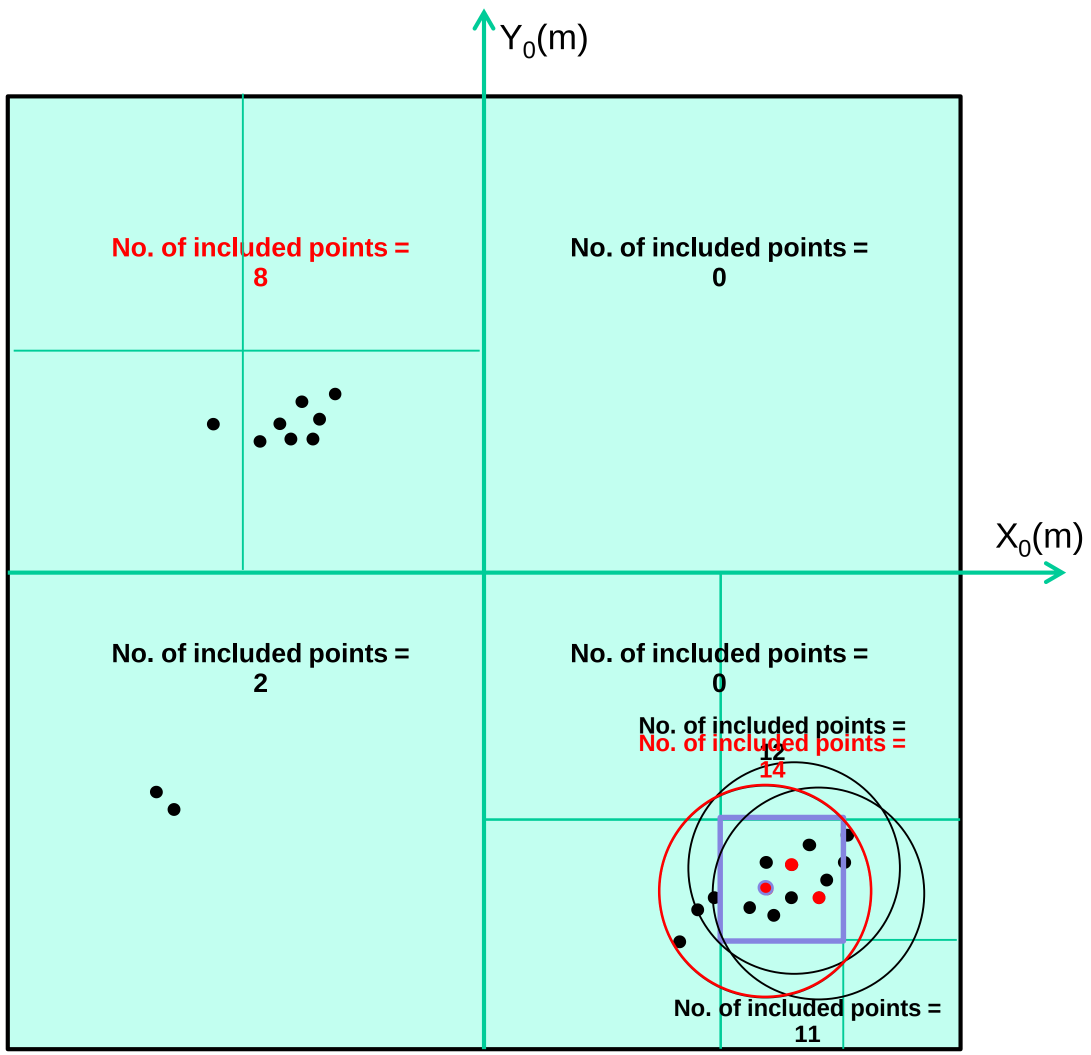
- **Fast Approach for Peak Detection: Coarse Peak Detection**



2D representation of coarse peak detection approach

Parameter-Domain Segmentation

- **Fast Approach for Peak Detection: Fine Peak Detection**



2D representation of fine peak detection approach

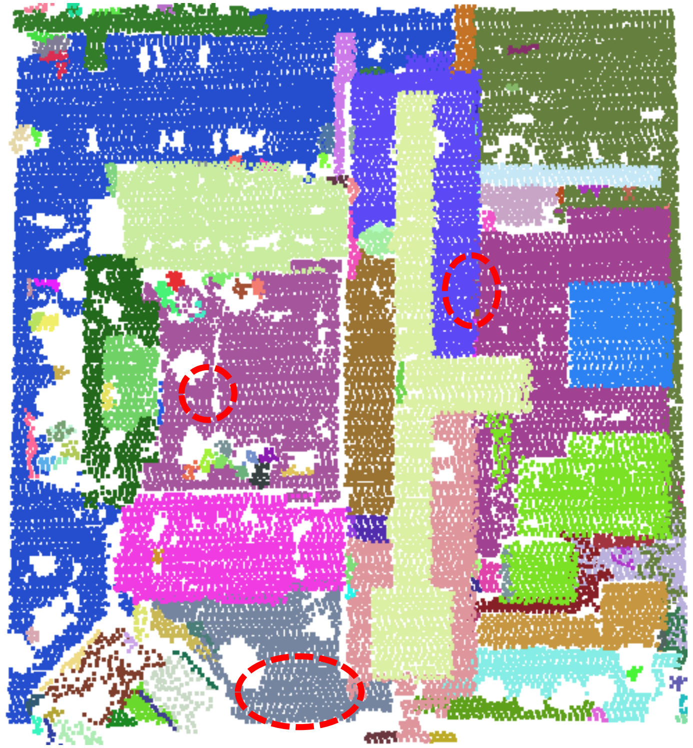
Parameter-Domain Segmentation

- **Brute-force Approach:**
  - Advantage: This approach will allow for the detection of the largest peak first, which might avoid over segmentation problems.
  - Drawback: low computational efficiency
- **Fast (Octree-based) Approach:**
  - Advantage: high computational efficiency
  - Drawback: This approach will not guarantee the detection of largest peak first, and this may lead to over segmentation problems.

Parameter-Domain Segmentation

- **Results from different peak detection methods:**

Aerial photo



Brute-force clustering approach result

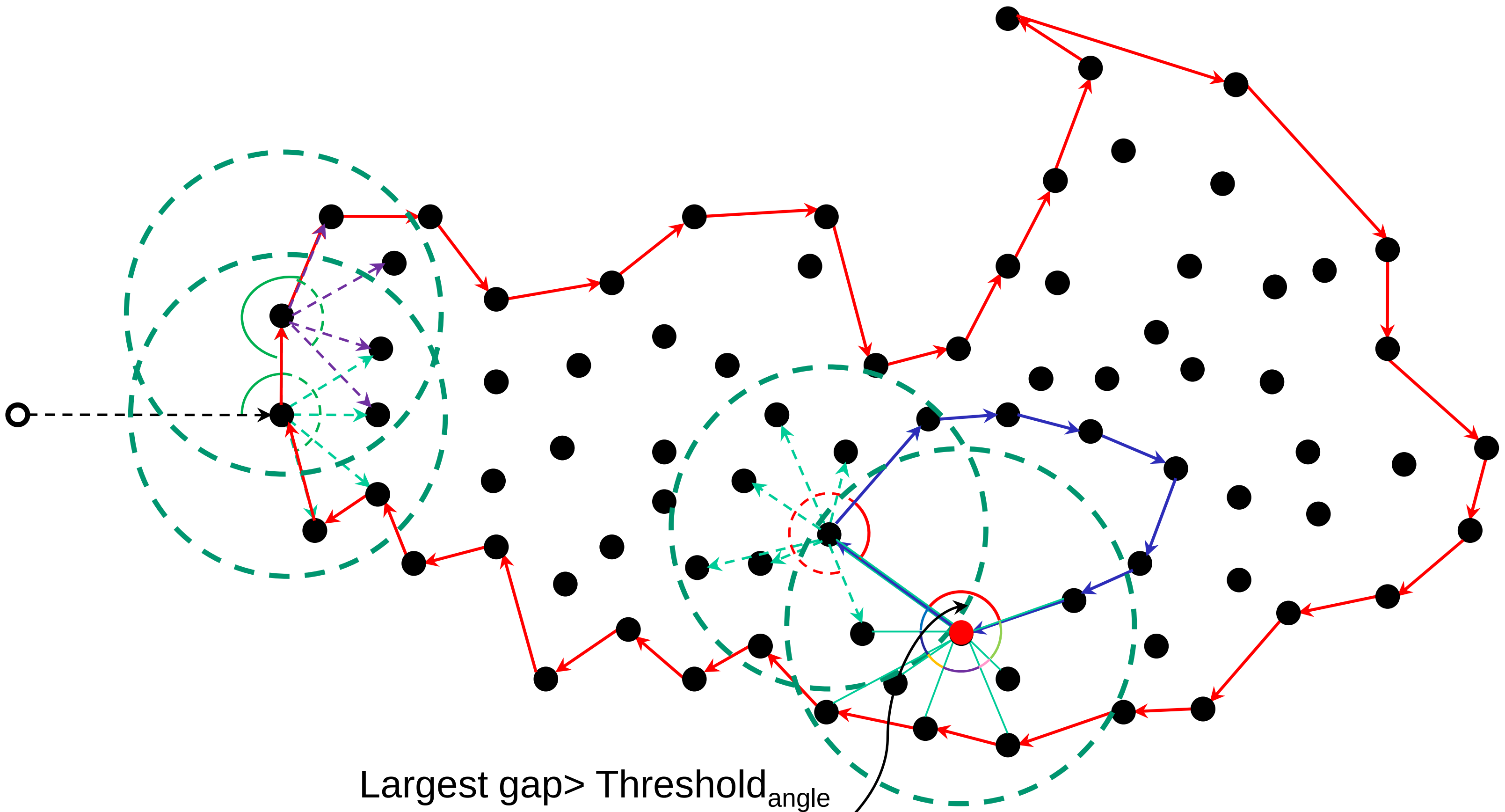
Octree-based clustering approach result

------- Over-segmentation

PURDUE UNIVERSITY

Boundary Detection: Hybrid Method

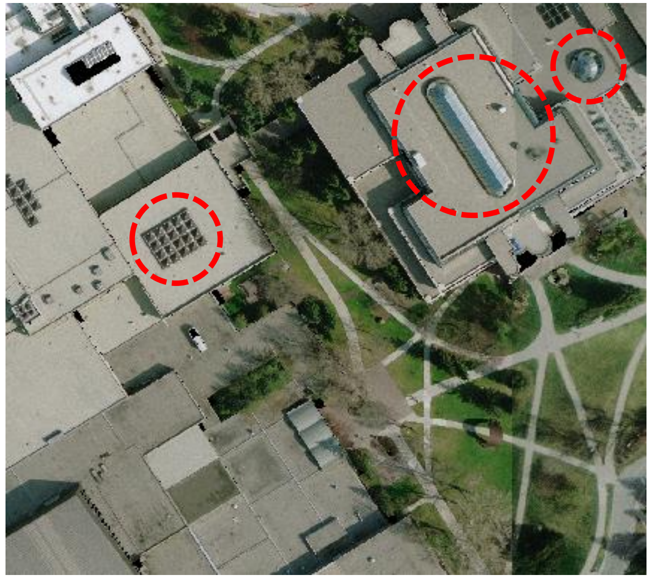
- **Minimum Convex Hull & Angular Gap Approach**



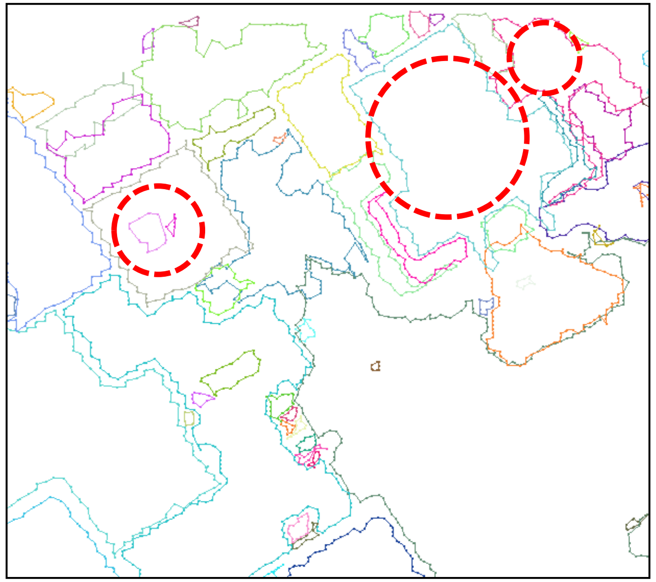
For outer boundary:
Boundary tracing: clock-wise
Angle check: clock-wise

For inner holes:
Boundary tracing: clock-wise
Angle check: counter clock-wise

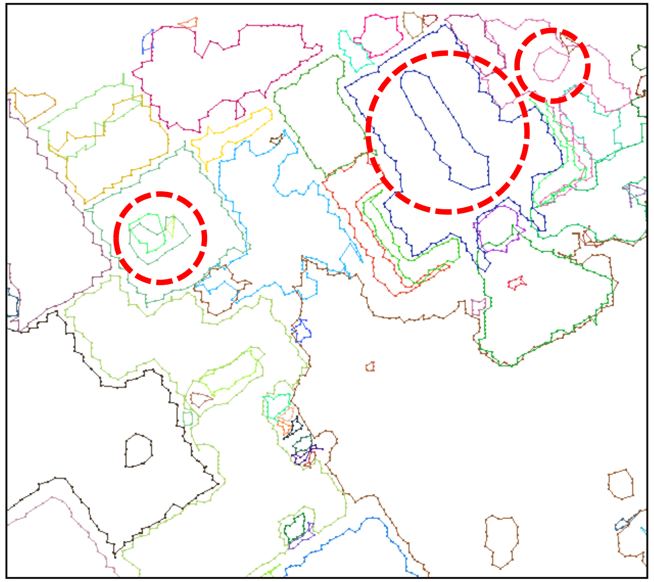
Boundary Detection Results



Orthophoto



Boundary detection
Minimum convex hull



Boundary detection
Hybrid method

The hybrid boundary detection is able to trace the boundaries of holes inside each cluster.

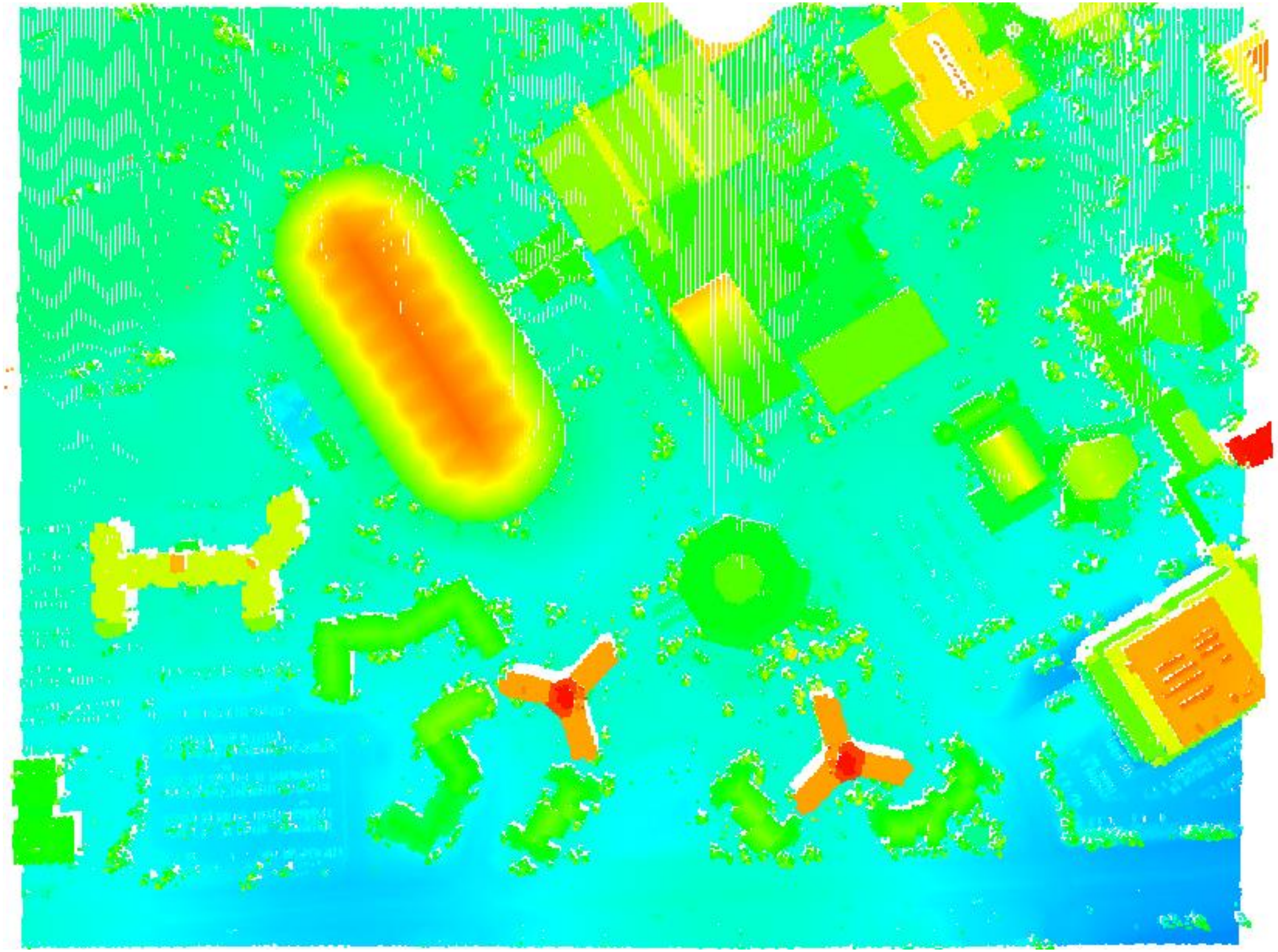
LiDAR Data Classification and Segmentation

- Orthophoto over the test area

PURDUE
UNIVERSITY

LiDAR Data Classification and Segmentation

- Original LiDAR data



PURDUE UNIVERSITY

LiDAR Data Classification and Segmentation

- Segmentation