The 2010 IEEE International Conference on Robotics and Automation

Scene Understanding in a Large Dynamic Environment through a Laser-based Sensing

H. Zhao, **Yiming Liu**, X. Zhu, Y. Zhao, H. Zha

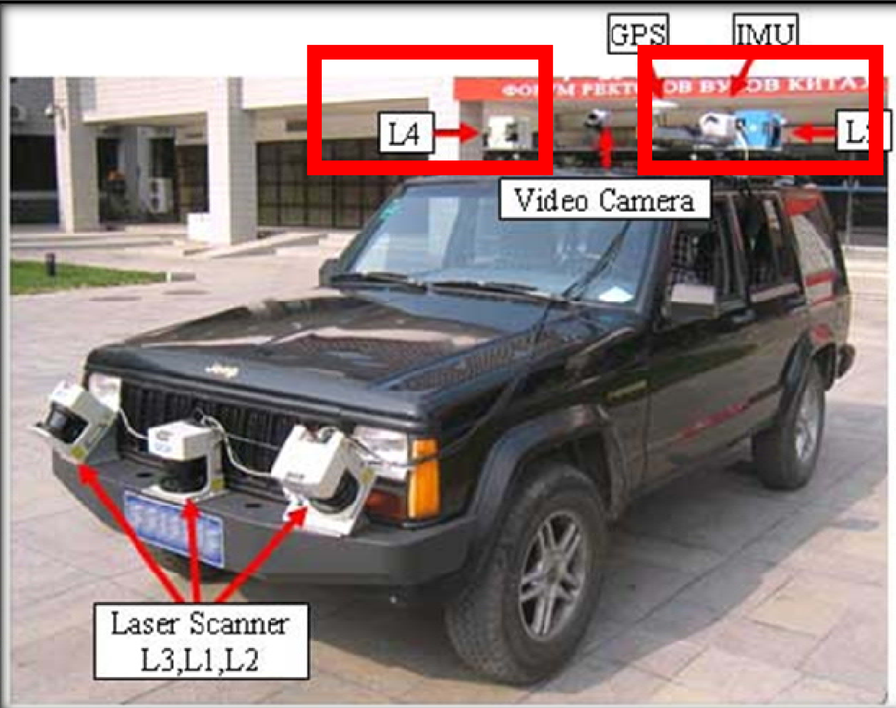
Peking University

Outline

- Introduction
- Problem formulation
- Framework
- Experimental results
- Summary
- Future work

Introduction – Data Acquisition

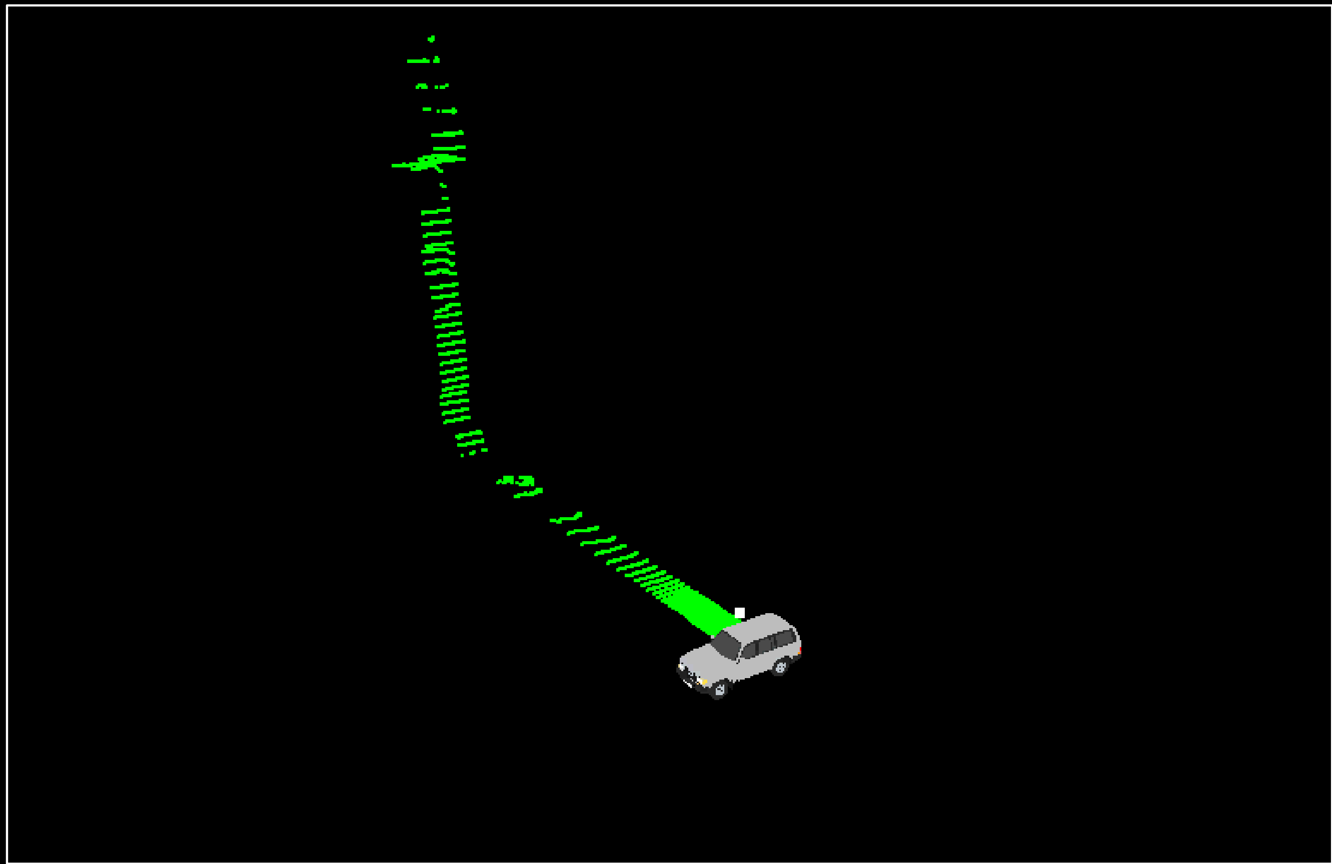
- We use a moving platform with SLAM to acquire the range data of the whole environment



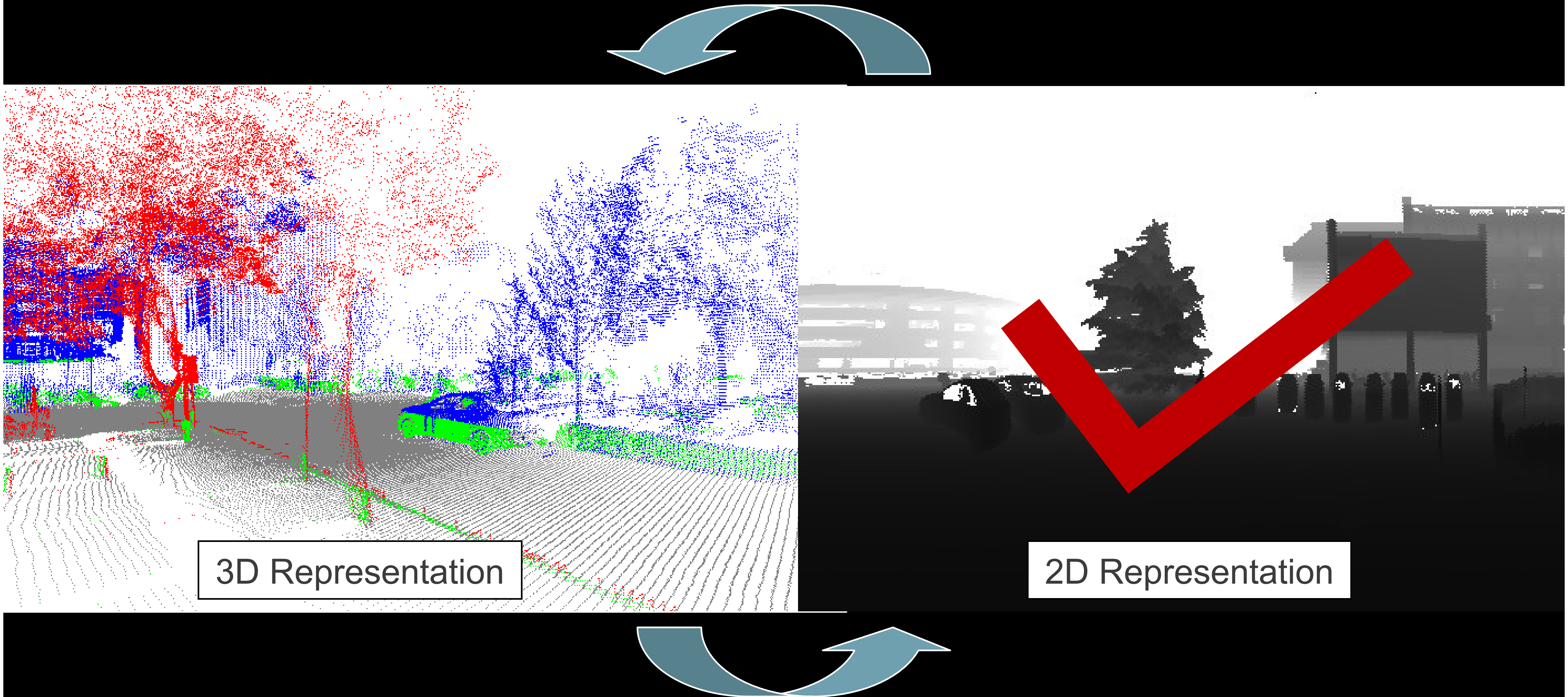
Laser #	Scan Mode	Major Purpose
L1	Horizontal	SLAM with MODT
L2	Downward	Road geometry
L3	Upward	Objects above the road
L4	Vertical Right	Objects to the right of the car
L5	Vertical Left	Objects to the left of the car

Our Platform

Introduction – Data Acquisition



Introduction – Data Acquisition

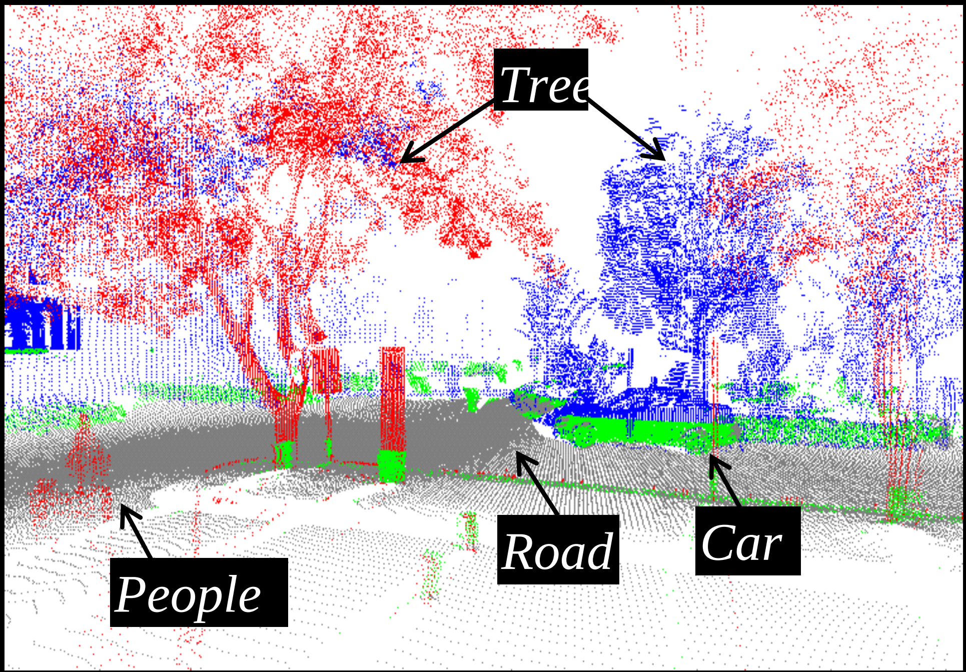


Equally convertible to each other

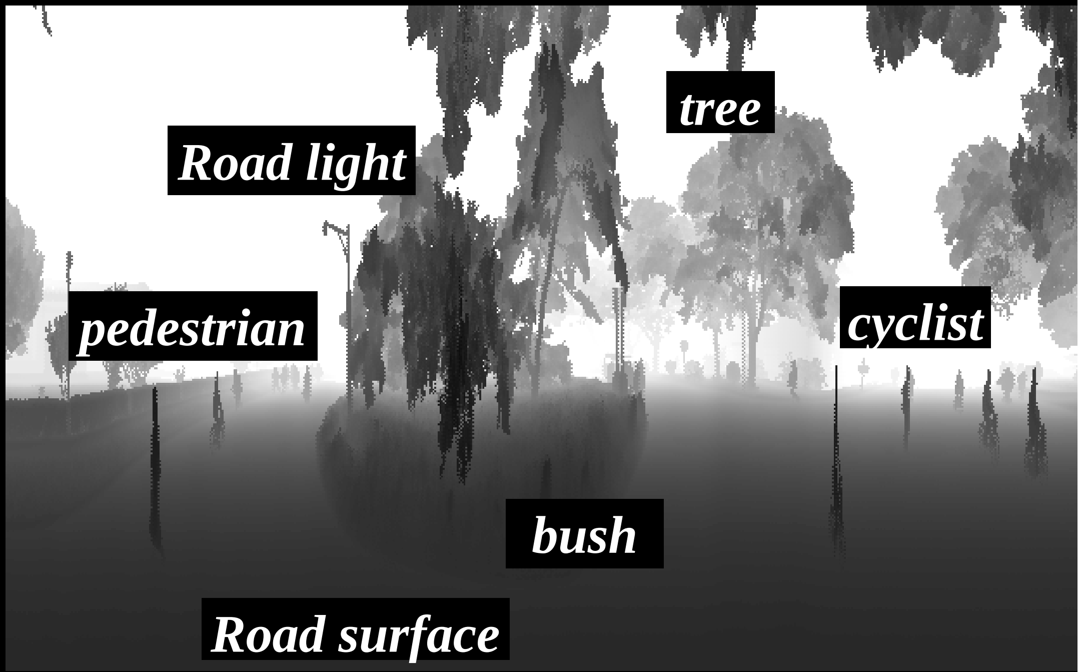
Same data organized in two different forms

Problem Formulation

- People can easily understand the scene



3D Laser Points



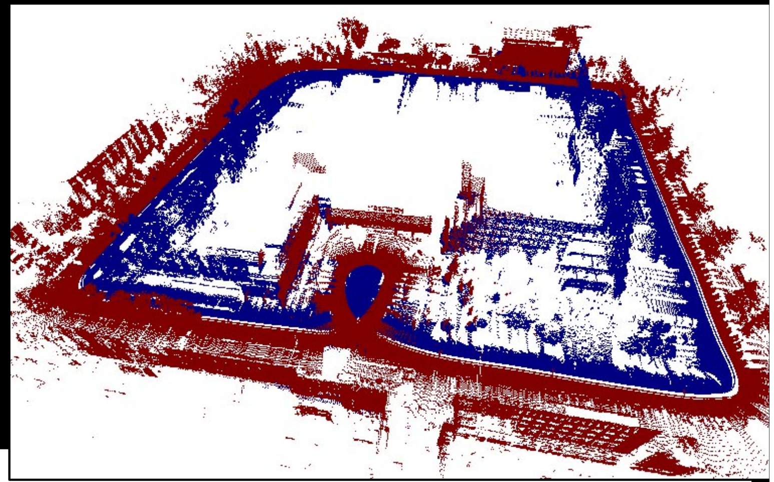
2D Range Image

Introduction - Our Objective

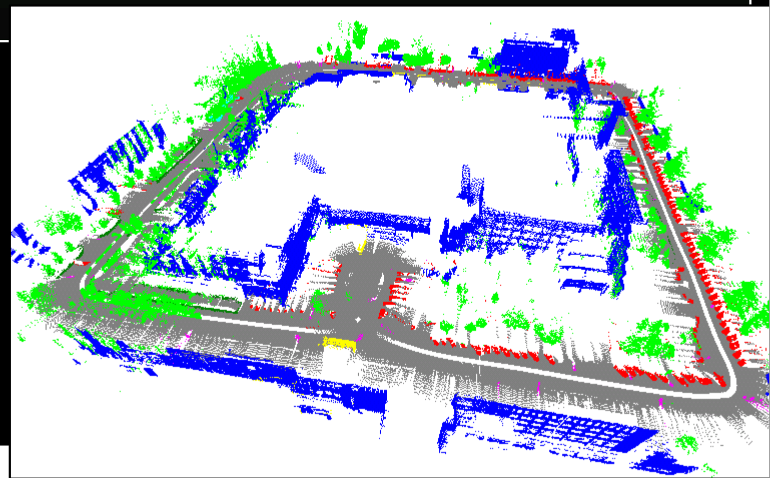
- We aim to provide a map with high-level representations.
- This map enables a robot to have semantic knowledge of the environment which is large and dynamic, such as objects, their types and so on.

Make the robot understand the scene!

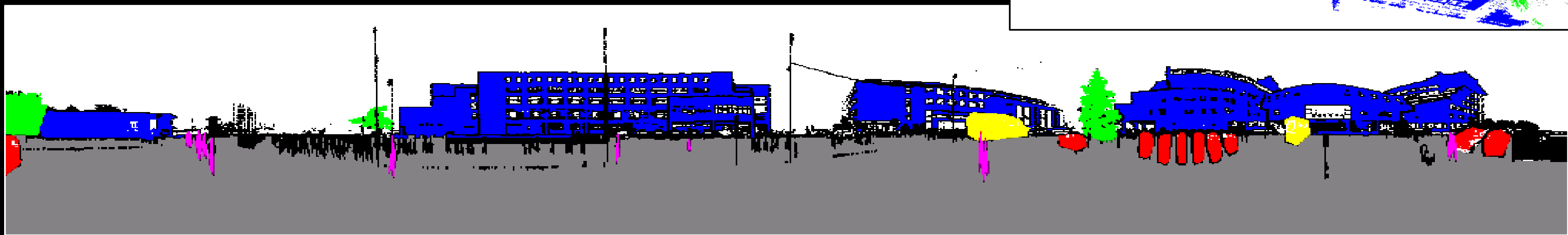
Problem Formulation



- **Input** - Range Image



- **Output** - Segments with semantics



Segmentation

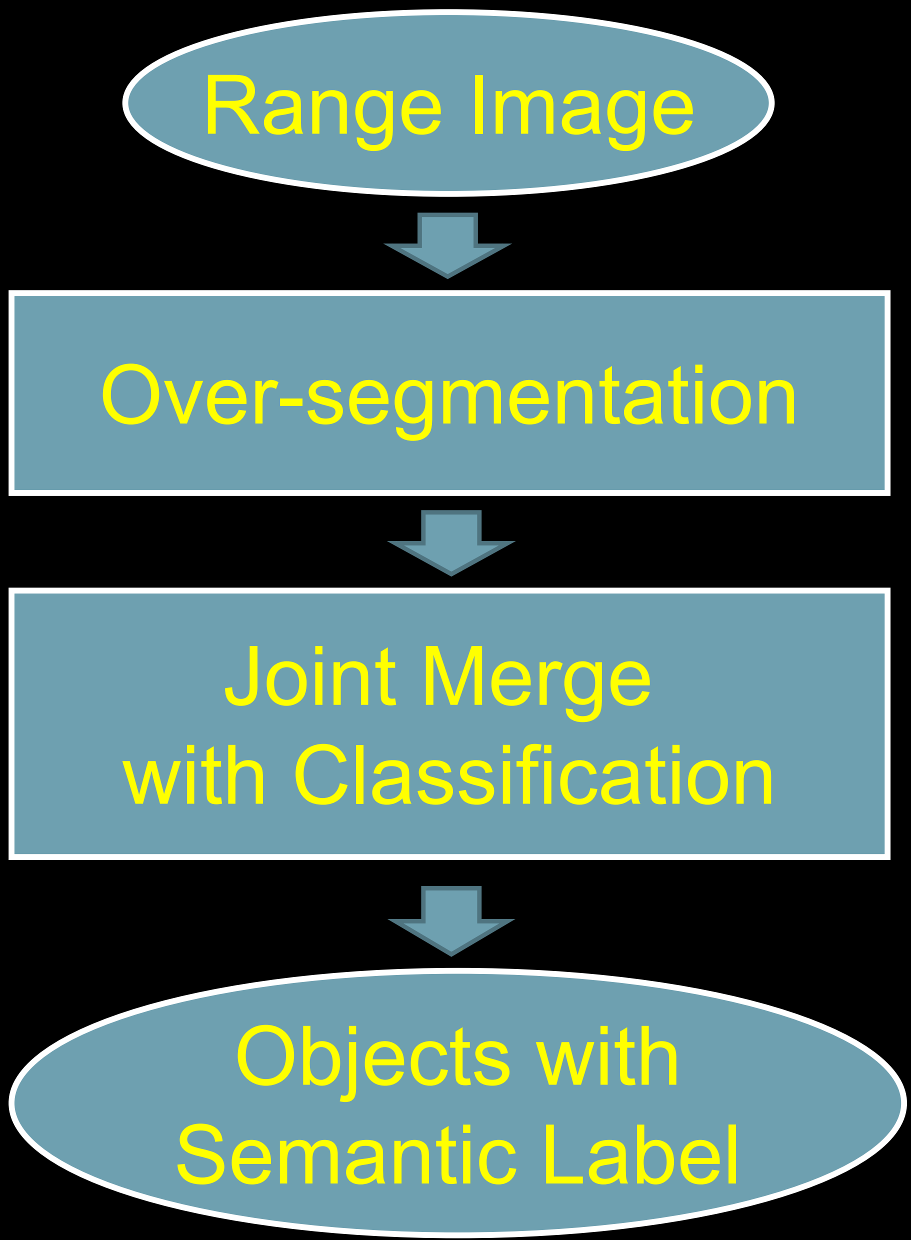
and

Classification

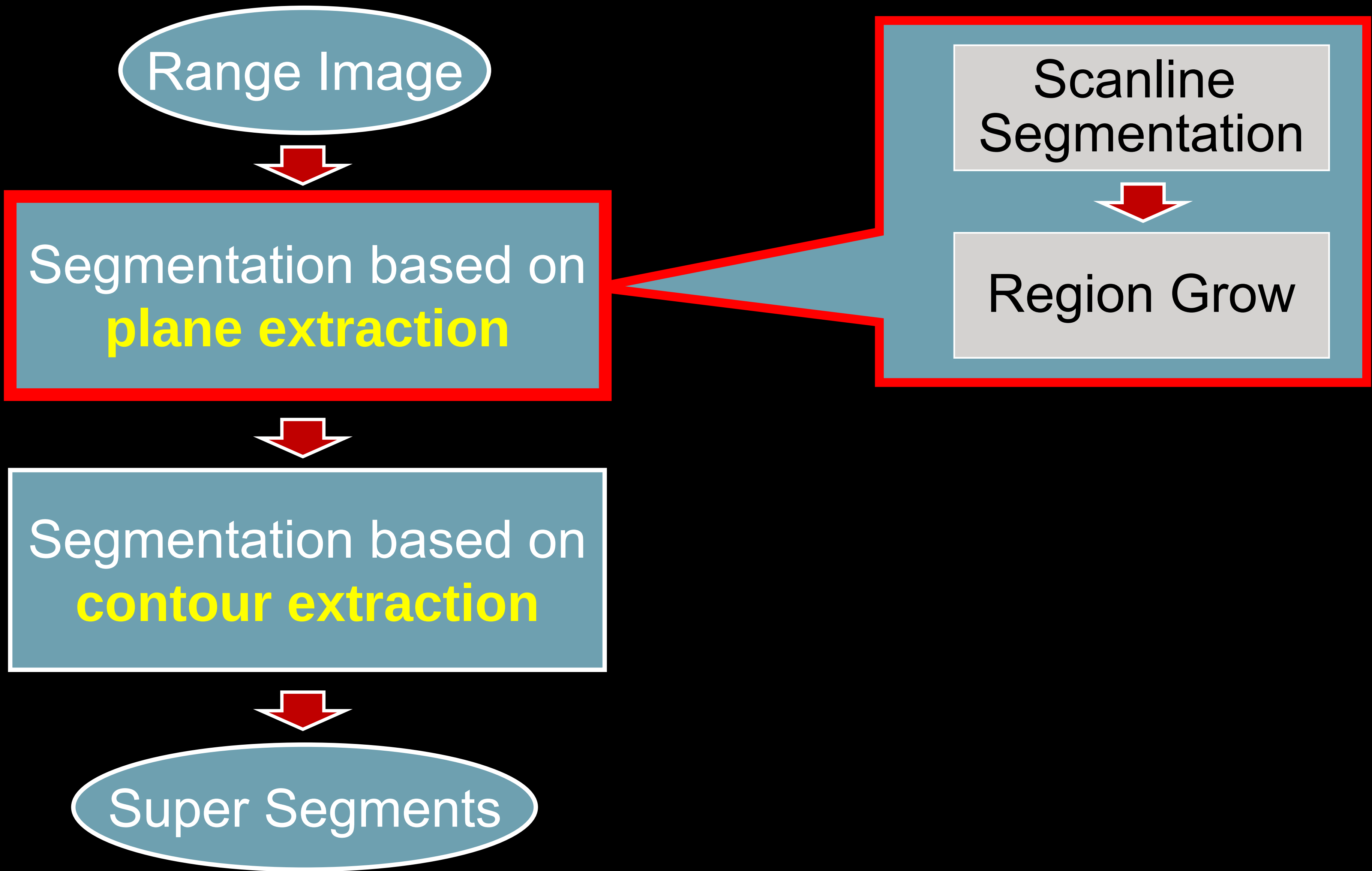
Traditional Method

- Sequential framework
  - segmentation -> classification
- Challenges
  - Many kinds of objects in complex environments
  - Based on an uniformed segmentation rule to all kinds of objects
    - Different objects might be segmented into one
    - One object might be segmented into different pieces
- Classification and segmentation should not be separated

Framework - Flowchart

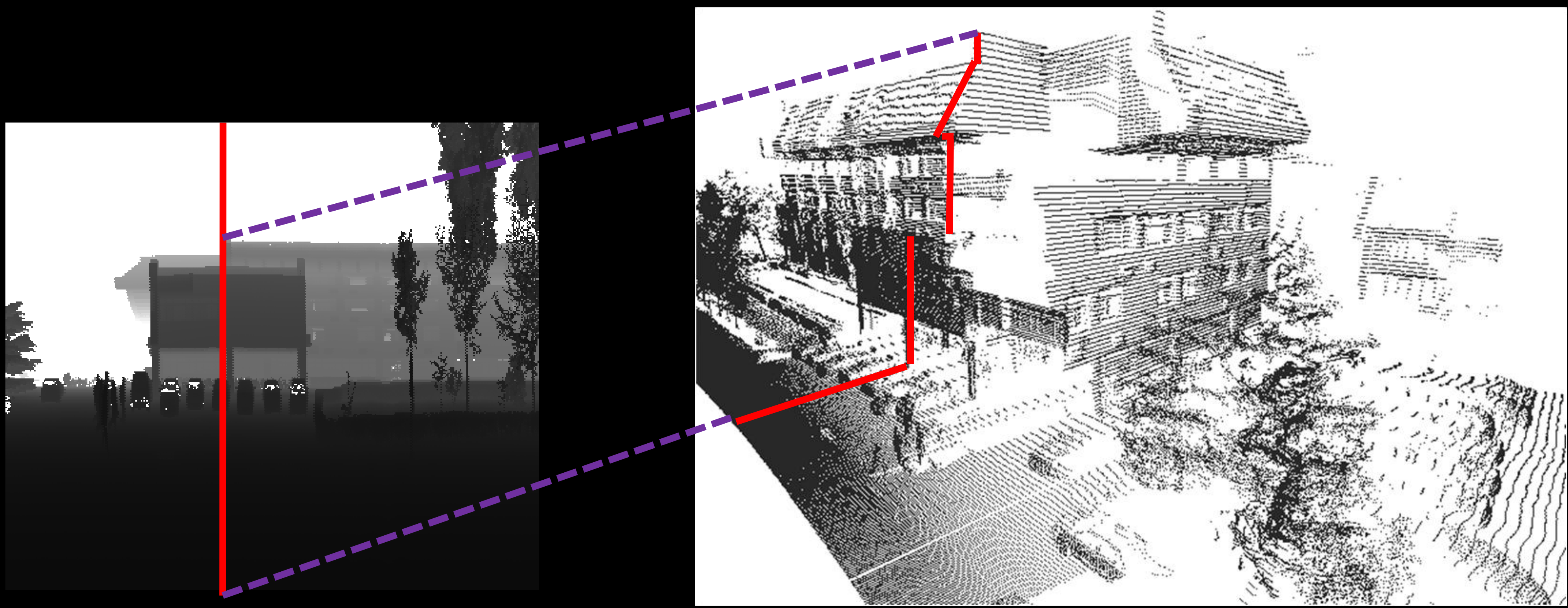


Over-segmentation



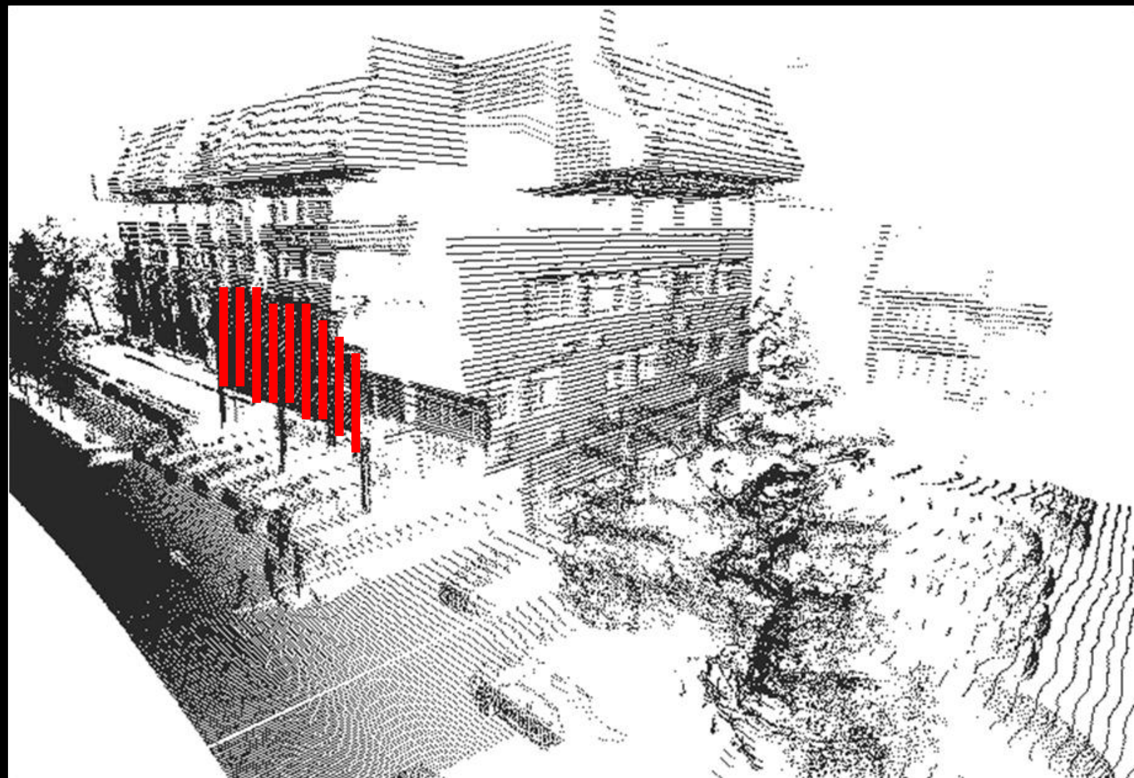
Plane extraction

- First, we separate every scanline into straight line segments.

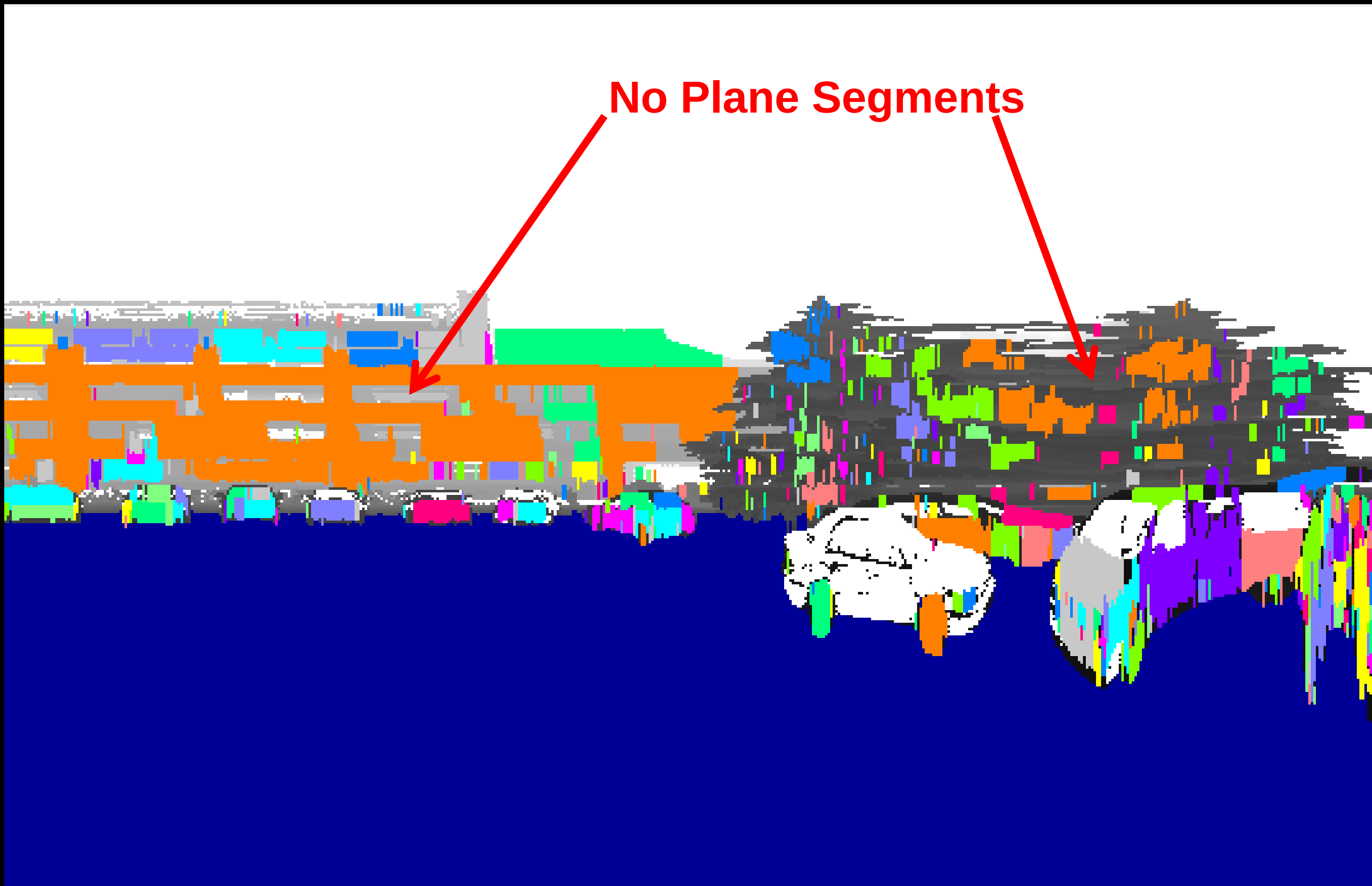


Plane extraction

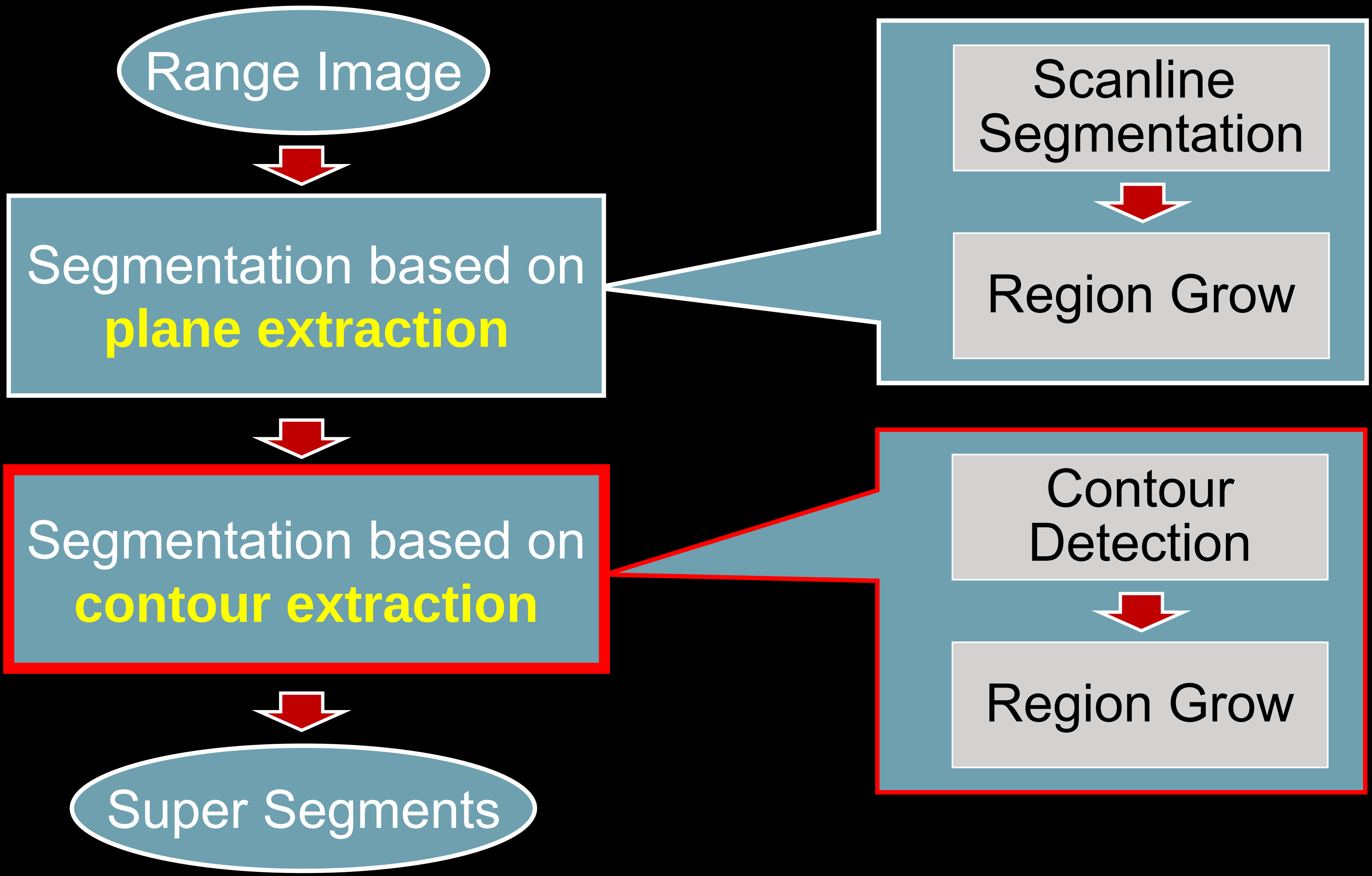
- Then, we grow all these straight line segments into planar regions.



Plane Extraction Results



Over-segmentation

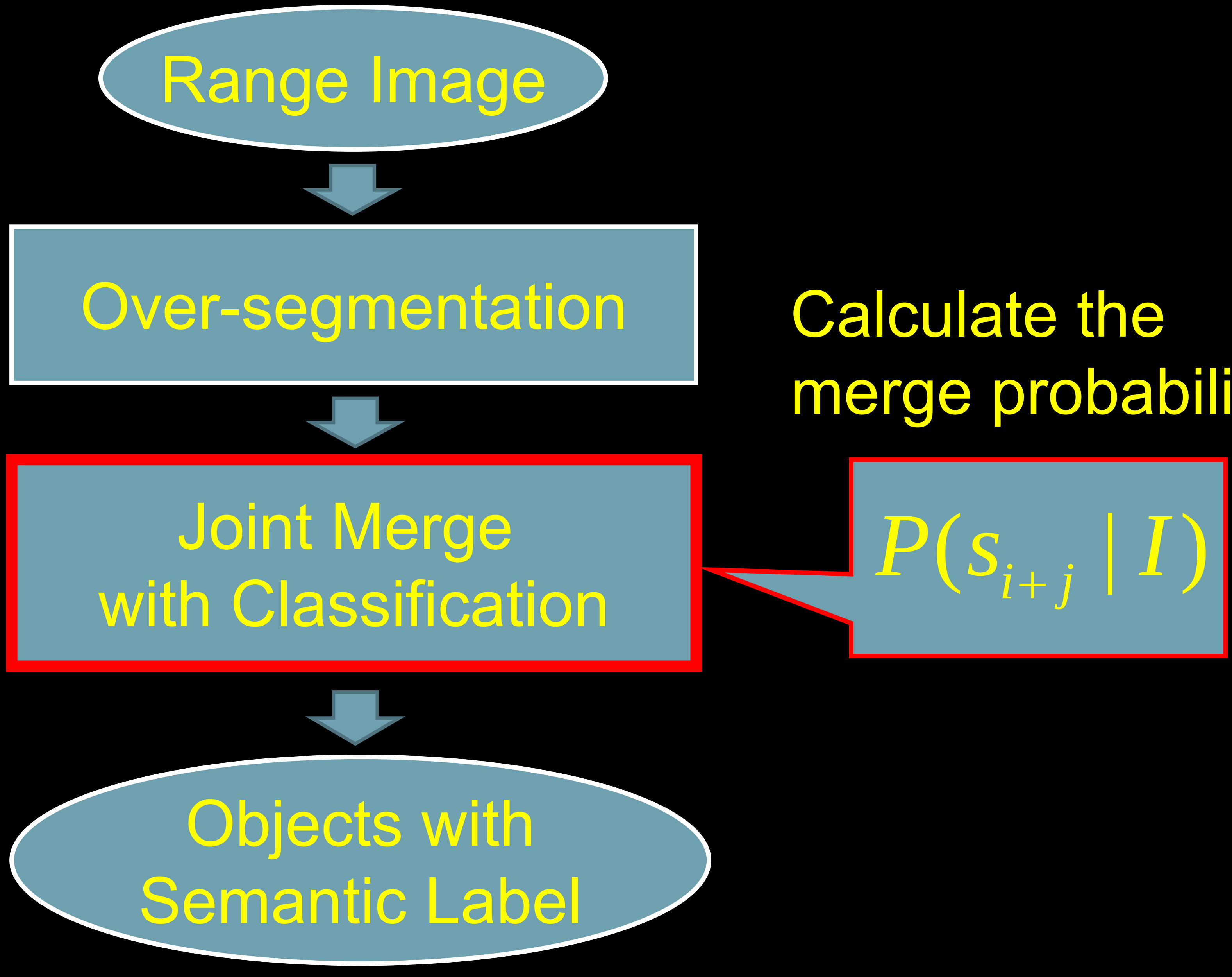


Contour Detection

Red Point: contour point

Over-segmentation Results

Flowchart Review



Joint Merge with Classification

$$P(s_{i+j} \mid I) \propto \sum_{l \in L} P(y_i = l \mid I) \cdot P(y_j = l \mid I) \cdot P(s_{i+j} \mid y_{i+j} = l, I)$$

The probability for a segment to be a certain class
Segment Classification

Given object class, the likelihood of two segments be the measurement to a single object
Likelihood

Segments Classification

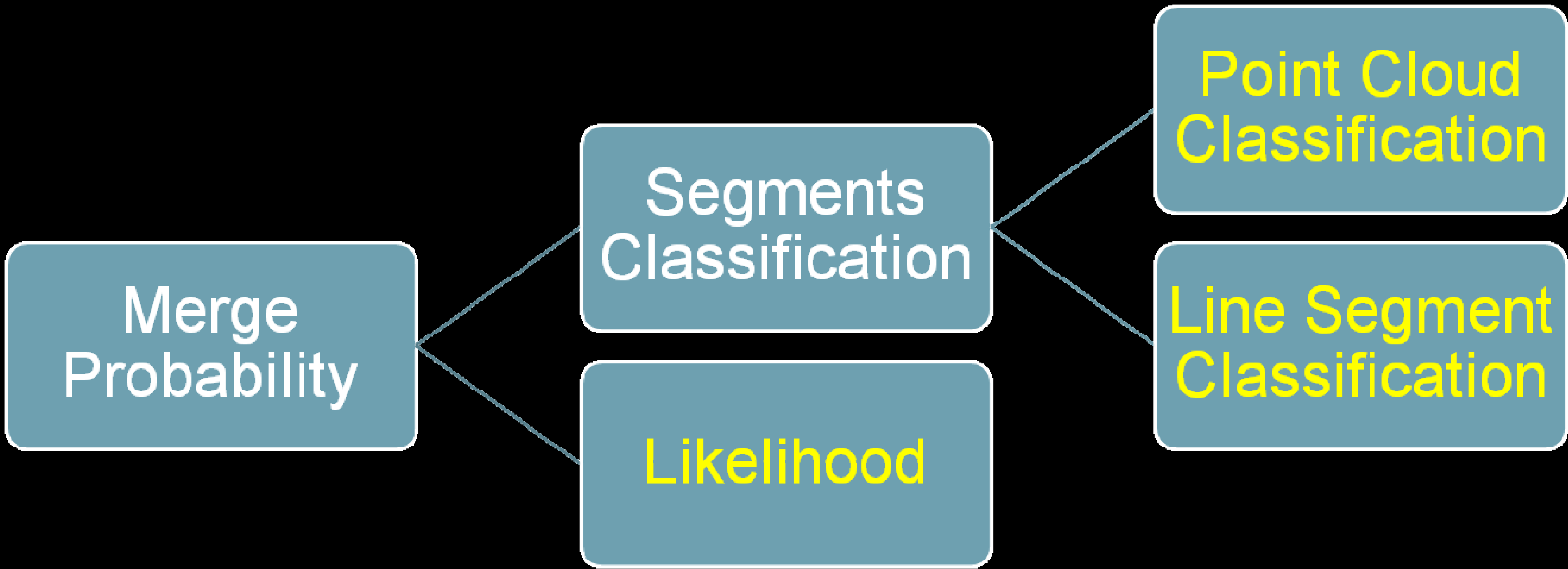
$$\sum_{l \in L} P(y_i = l \mid I) \cdot P(y_j = l \mid I)$$

$$P(y_i = l \mid I) = \frac{1}{Z} P\left(\bigcup_k y_i^{(k)} = l \mid I\right) \bullet \prod P(y_i^{(k)} = l \mid I)$$

Points Cloud Classification

Line Segment Classification

Joint Merge with Classification



Segments Classification

- Point Cloud Classification
  - SVM
- Line Segment Classification
  - Naive Bayesian Classification

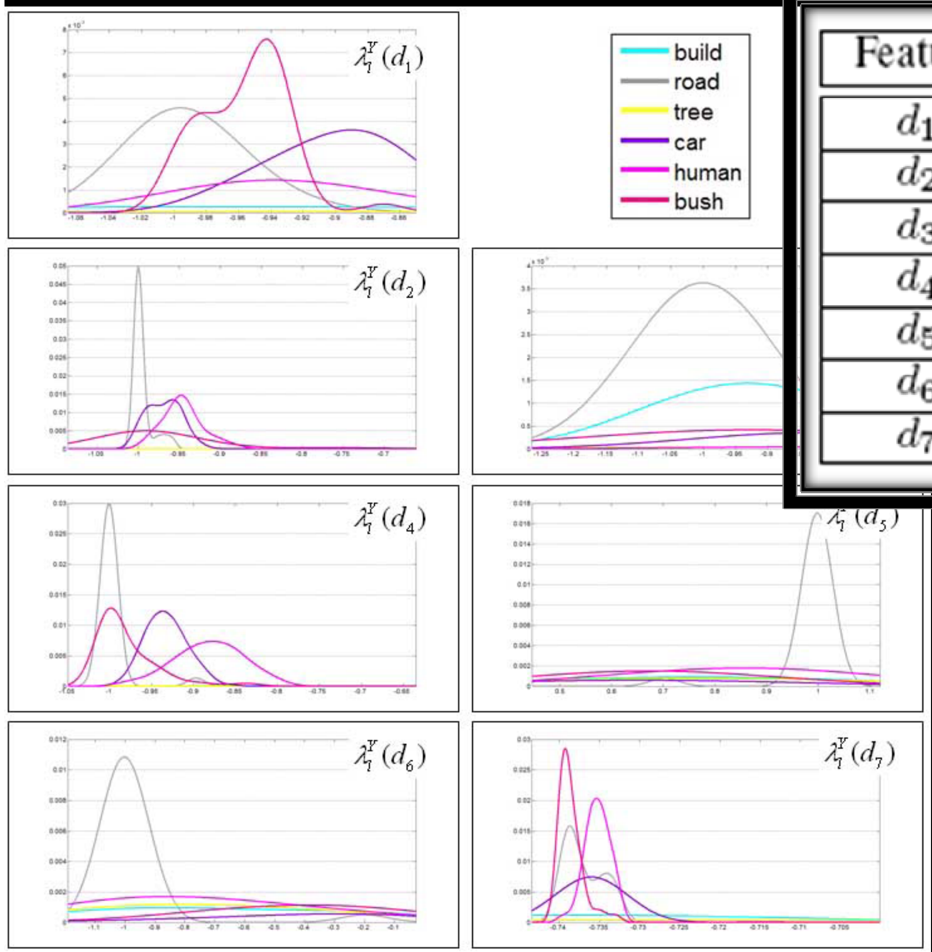
Training Sample

- We only use a small number of samples to train the point cloud classifier.

Class	Line Segments	Point Clouds
Building	9394	96
Road	10714	23
Tree	4122	148
Car	6080	41
People	394	120
Bush	1176	39
Bus	253	1
Total	32133	468

Feature Selection

- SVM - We selected 7 most discriminative features among more than 30 features

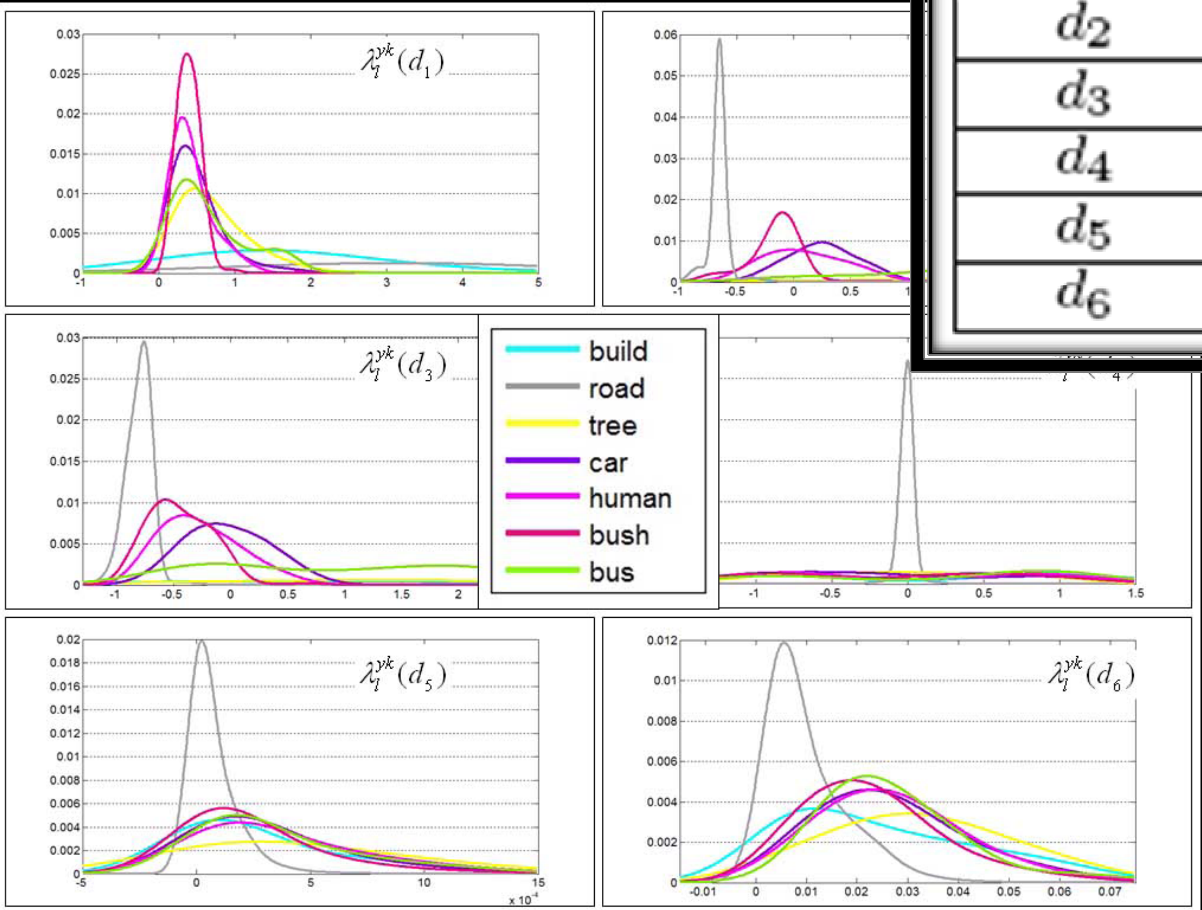


Feature	Definition
d_1	minimal height value
d_2	maximal height value
d_3	ratio of boundary point number vs total point number
d_4	mean of height values
d_5	variance of a histogram distribution on normal vectors
d_6	major picks of a histogram distribution on normal vectors
d_7	ratio of width vs. length

Feature Selection

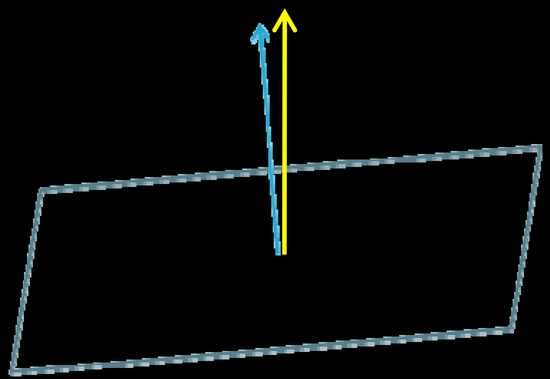
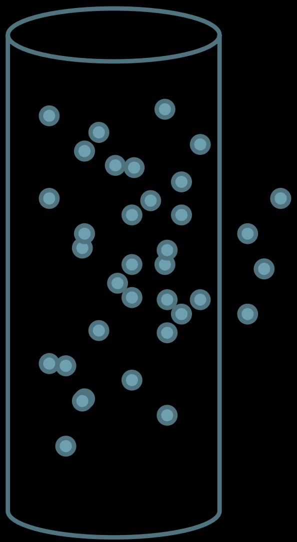
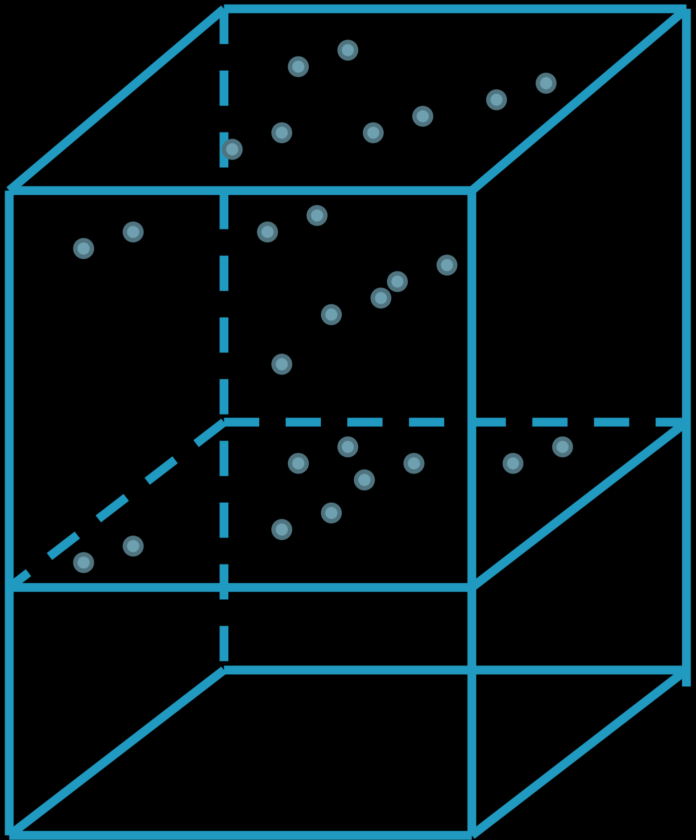
- Naive Bayesian Classification - We selected 6 features

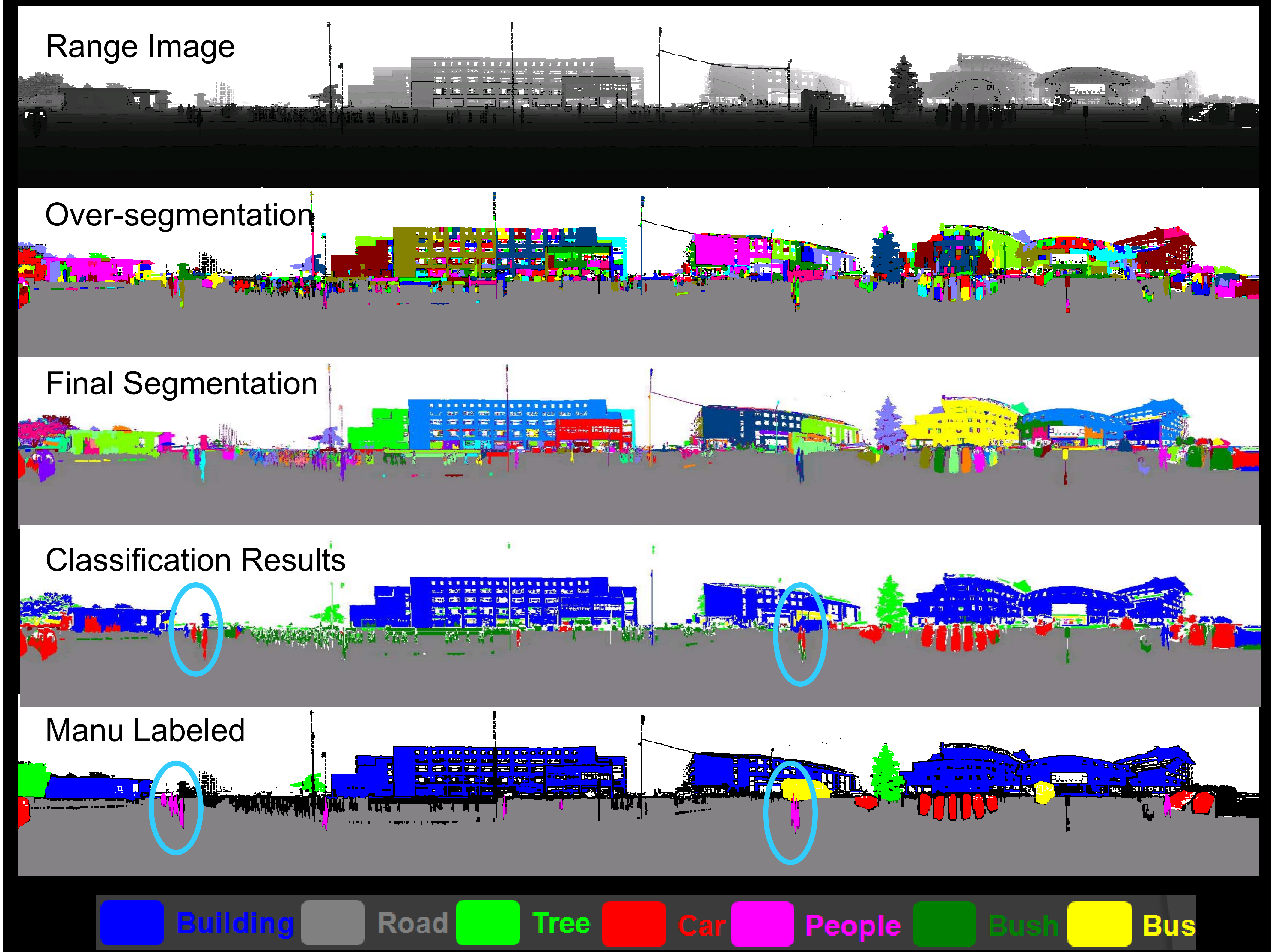
Feature	Definition
d_1	length of the scan line segment
d_2	maximal height value
d_3	minimal height value
d_4	Z factor of the directional vector
d_5	mean of line regression
d_6	variance of line regression



Likelihood

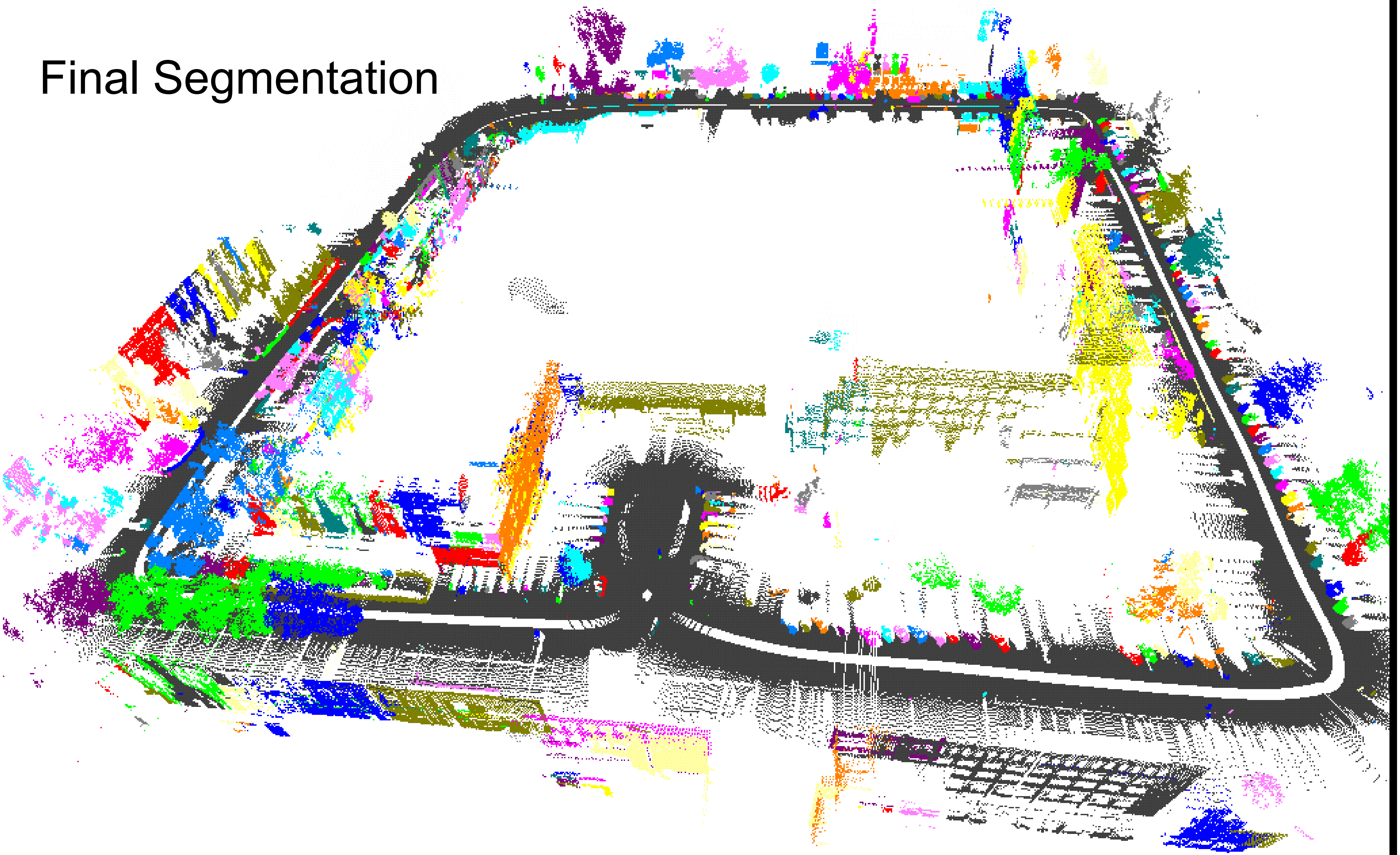
- 7 classes, 7 models
  - Plane fitting for road and building
  - Cube fitting for car, bus and bush
  - Cylinder fitting for people
  - Line fitting for tree

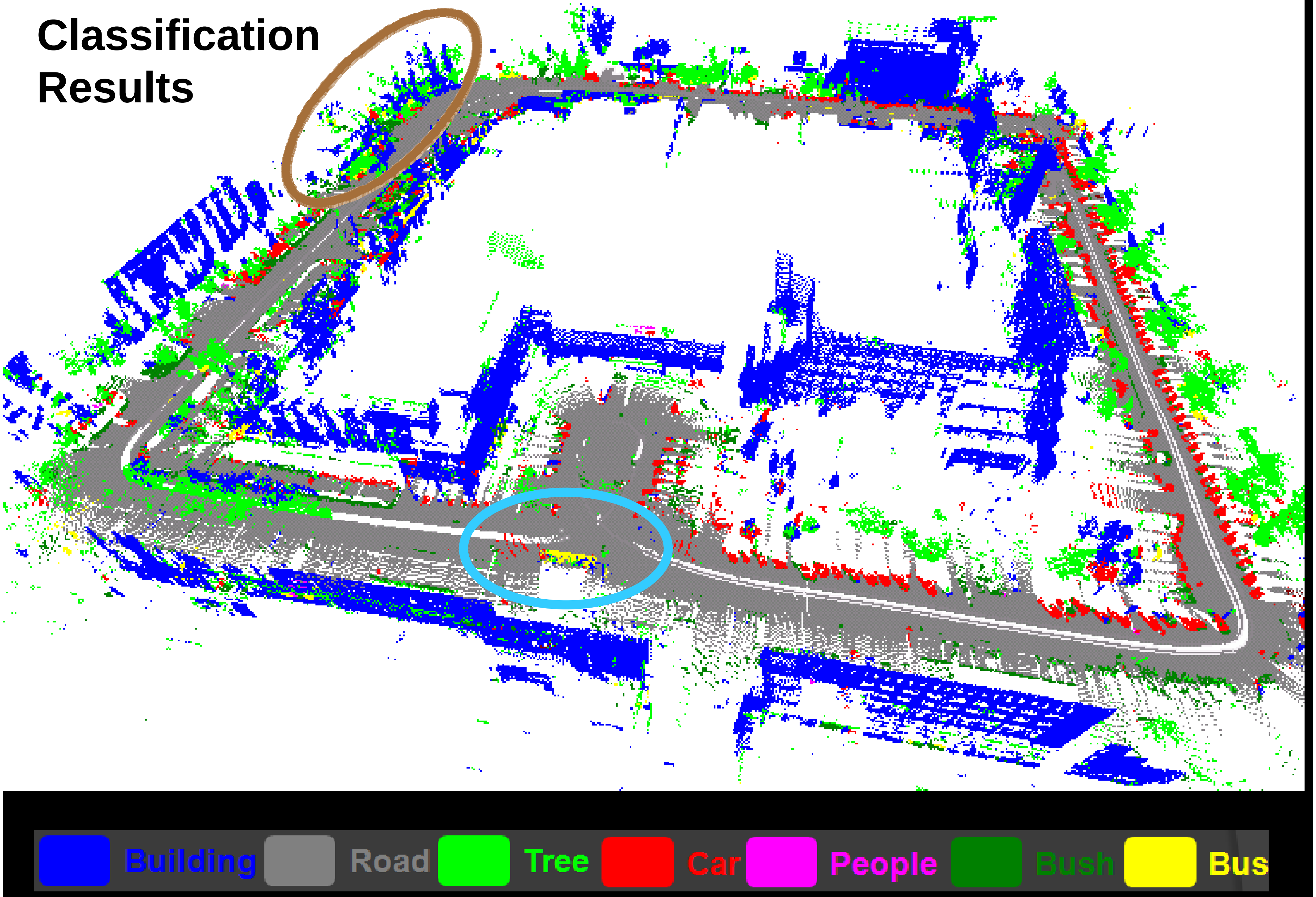


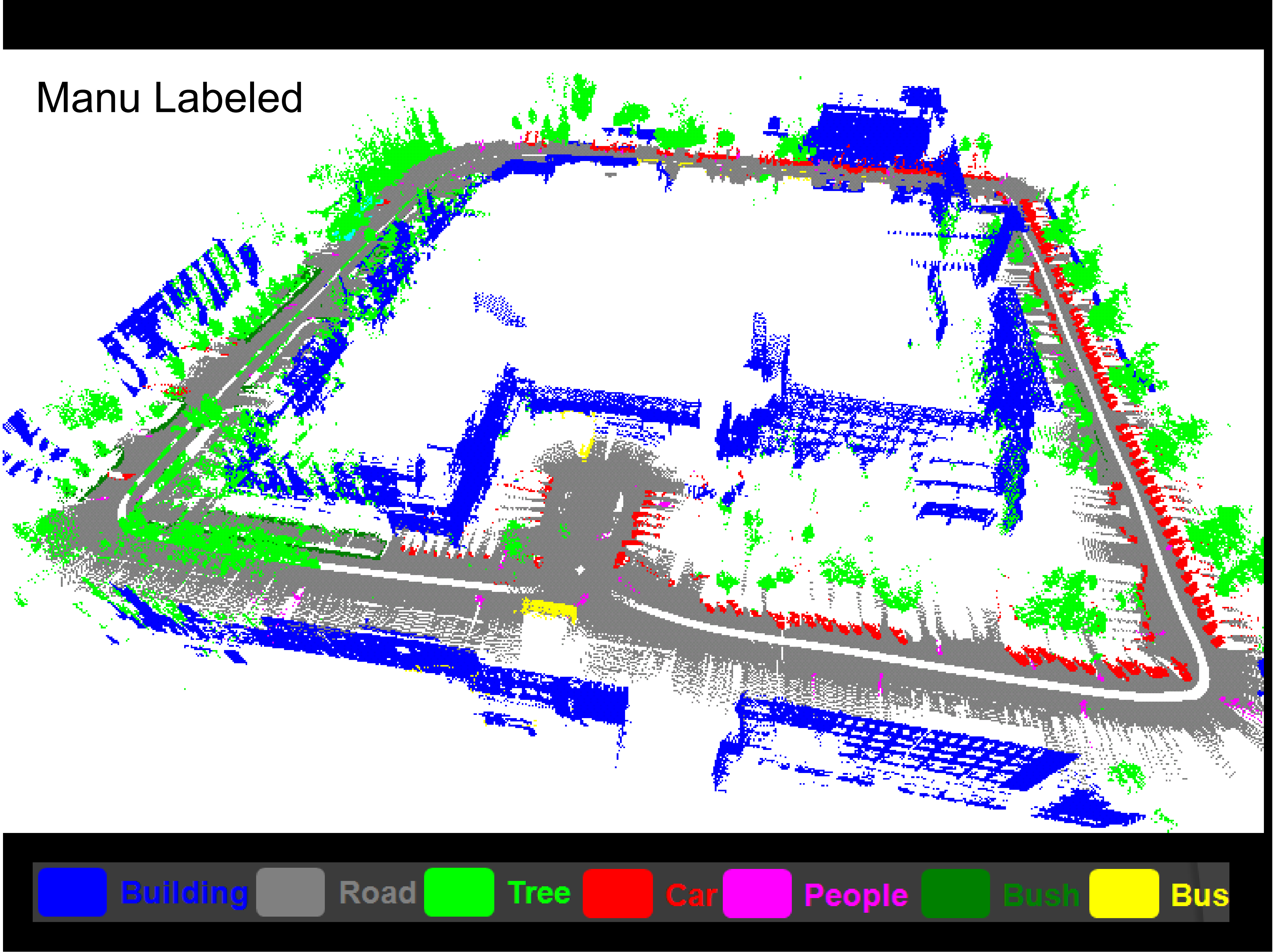
Range Image
Over-segmentation
Final Segmentation
Classification Results
Manu Labeled
Building
Road
Tree
Car
People
Bush
Bus

Final Segmentation



Classification Results




Manu Labeled
Building
Road
Tree
Car
People
Bush
Bus

Summary

- We develop a framework of joint segmentation and classification.
- The experimental results are encouraging.

- But there are still problems to be solved
  - Implementation of the framework needs to be improved.
  - Classification accuracy, especially people, are not satisfying due to limited training samples and partial observation.

Future work

- Improve our framework
  - How to deal with the segments containing no line segment
  - Points should be a special form of lines
- Make more training samples
  - We can make it together
  - Our data are available in

http://poss.pku.edu.cn

Thank you!