Classification of Moving Objects using Laser Scan Data

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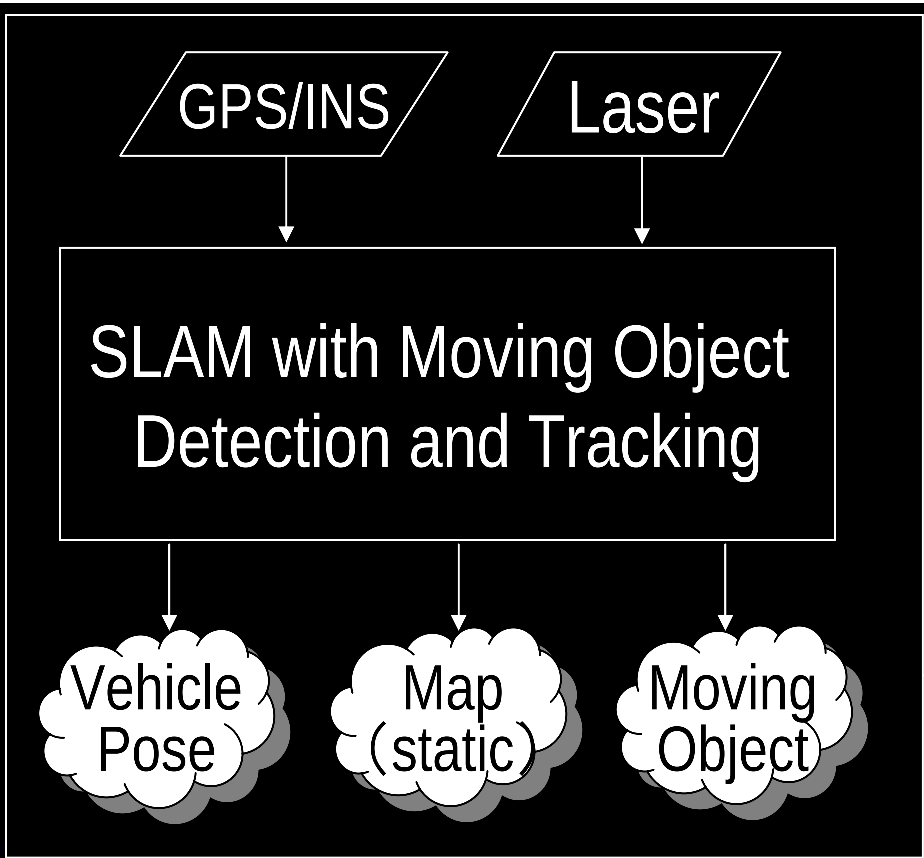
Platform 1

- **An Intelligent Vehicle**
  - Achieve an advanced perception at a large populated environment so that to enhance driving safety and collect data.

- **Three Problems**
  - Localization
  - Mapping
  - Mobile objects' detection, tracking and classification

A Laser-SLAM in Dynamic Environment (ICRA08)

Framework



Observation (clusters)

Control Input

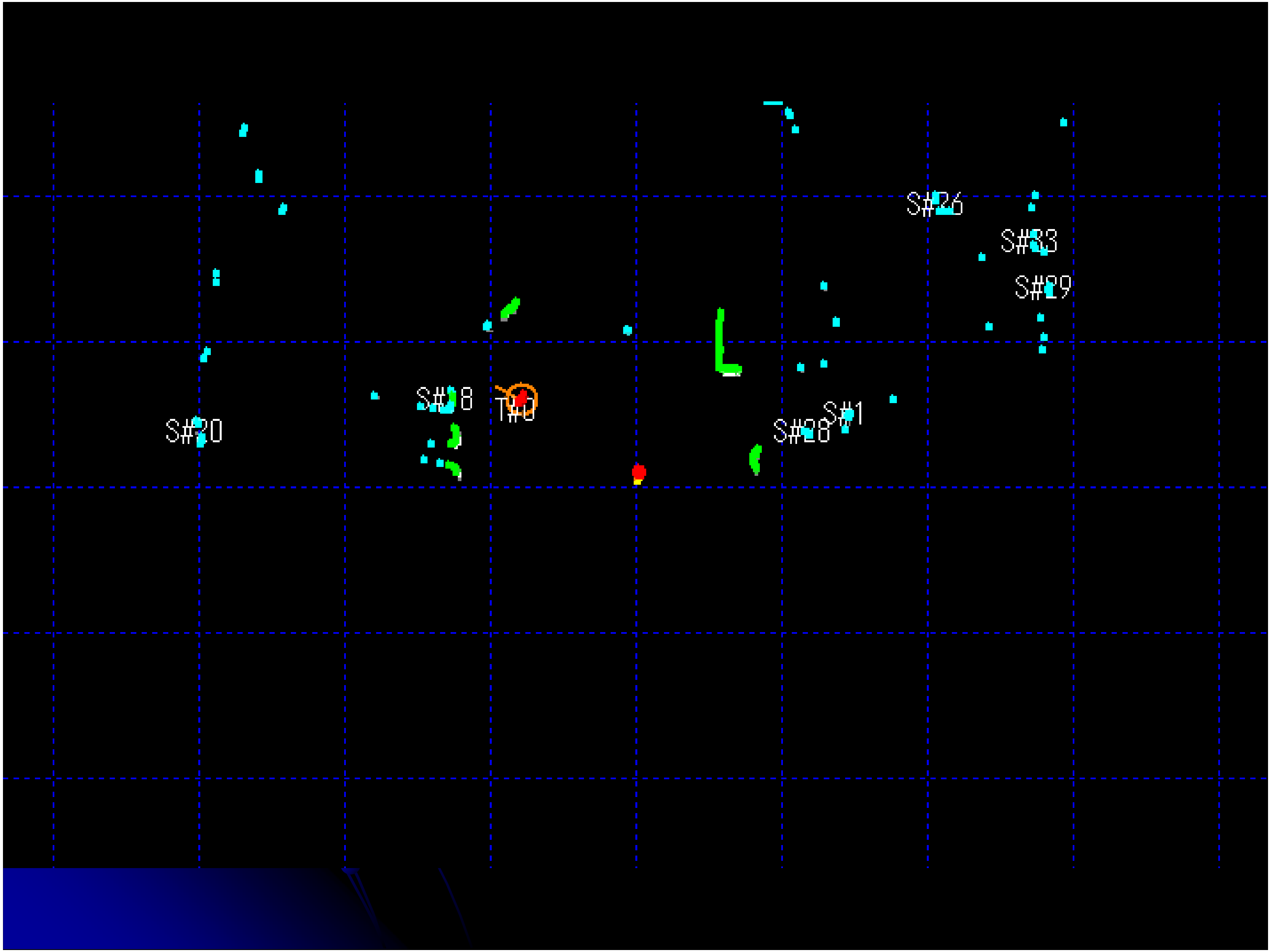
$$p(x_k, y_k, s_k, m \mid z_{0:k}, u_{0:k})$$

Vehicle pose

Moving object

Seed

Static object (map)


S#26
S#33
S#29
S#18
T#0
S#20
S#1
S#28

Needs from Platform 1

A **classification** method is required, where,

- **Input:**

  the laser measurements of the object from time S to time K,

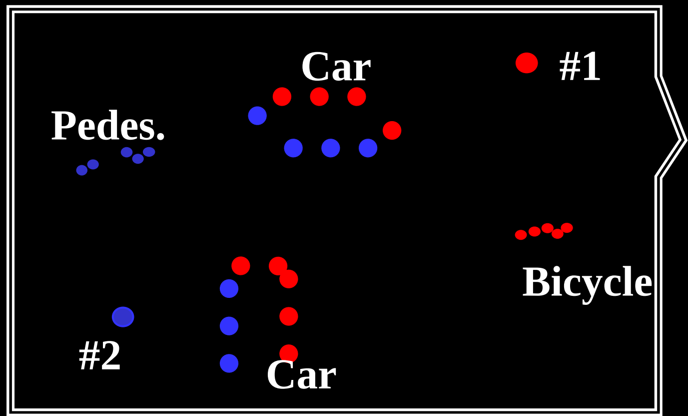
- **Output:**

  Classify the object to be a single person, a group of people, a bicycle or a car.

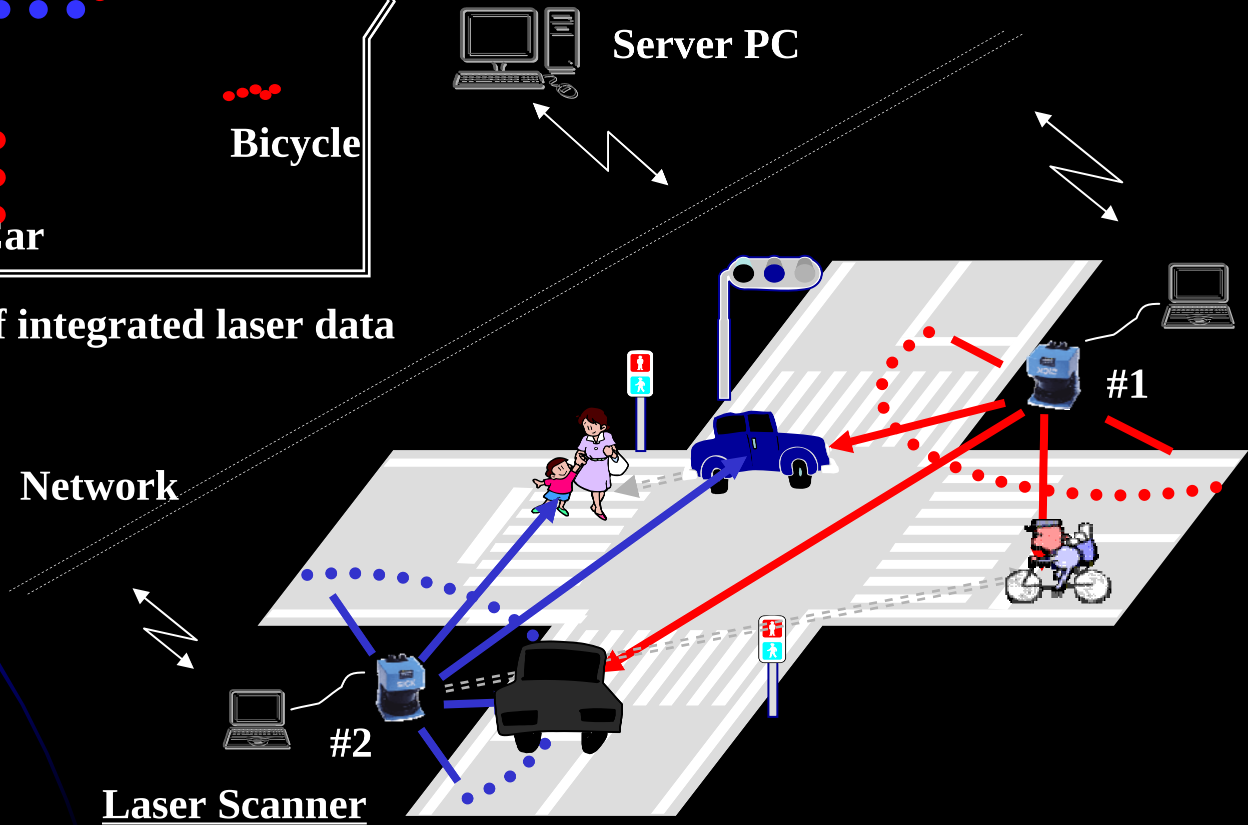
Platform 2

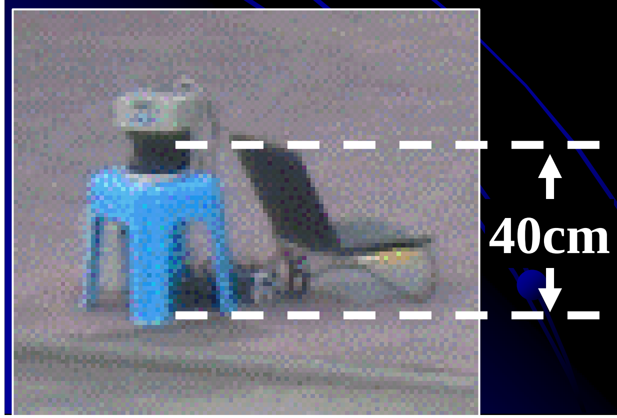
Network Sensing

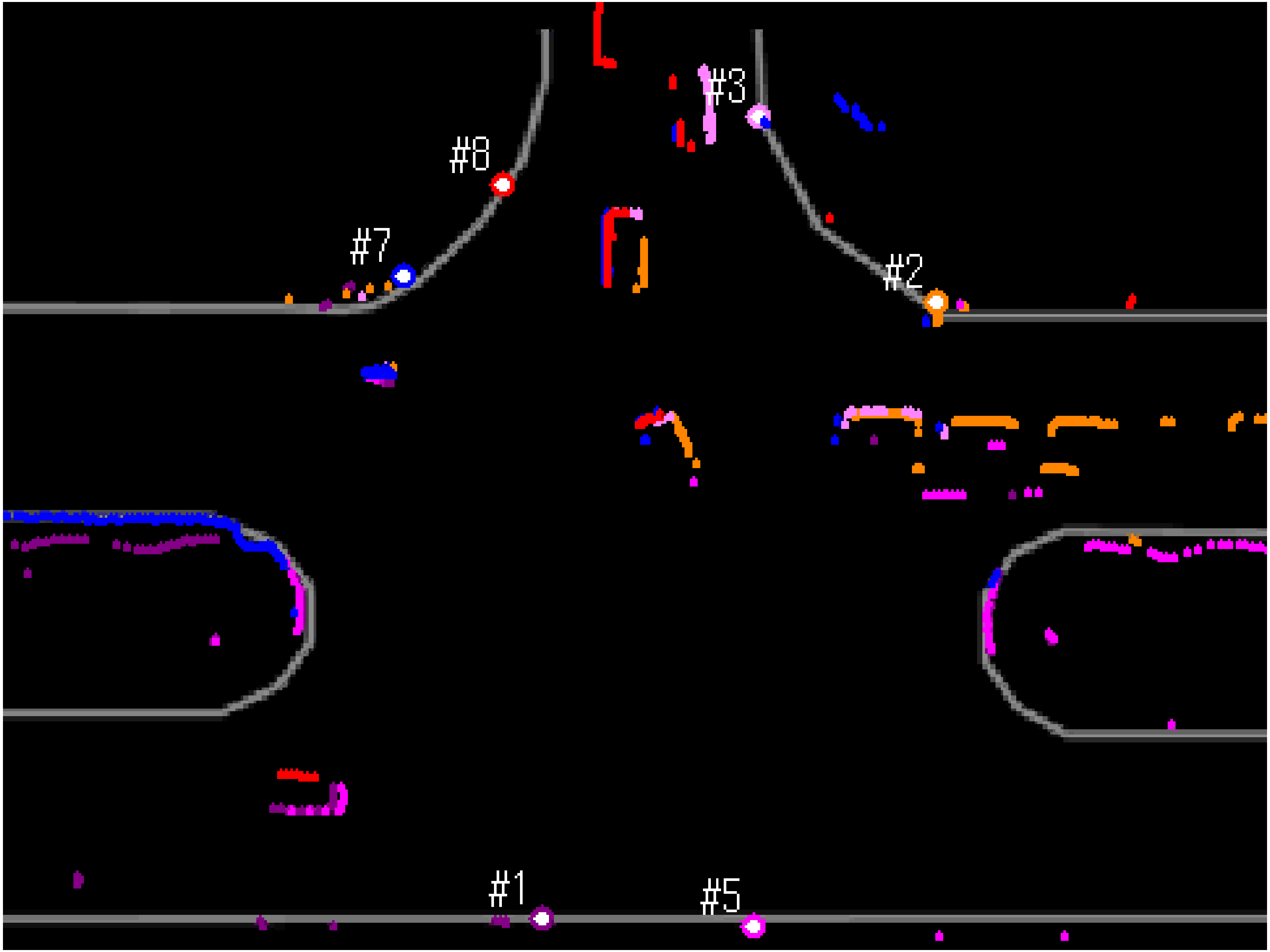
- Sensing the moving objects of a dynamic environment using a network of laser range scanners.



An image of integrated laser data



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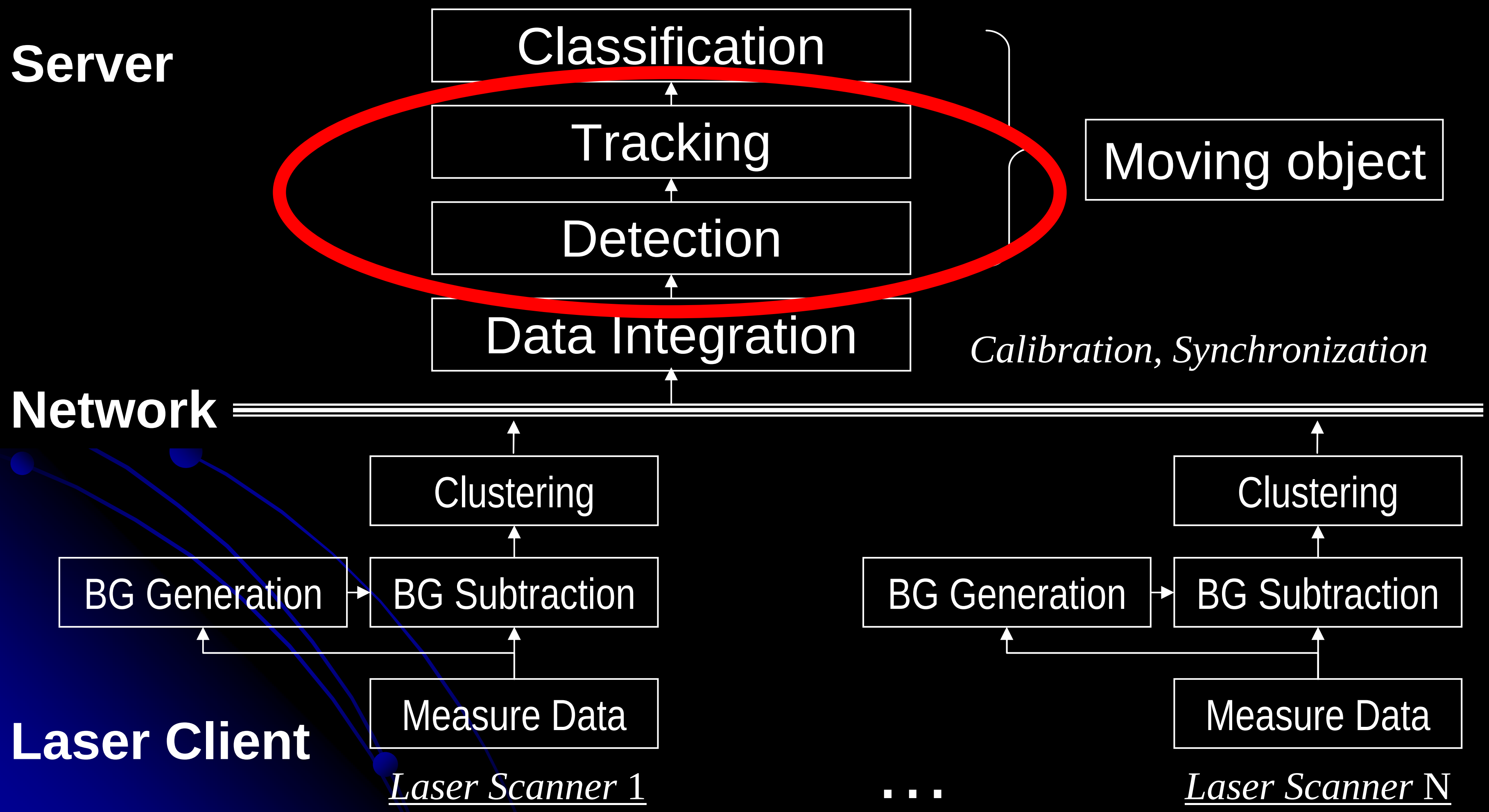
Moving Object Detection and Tracking using a Network of Laser Scanners (ITSC08)



Needs from Platform 2

A **classification** method is required, where,

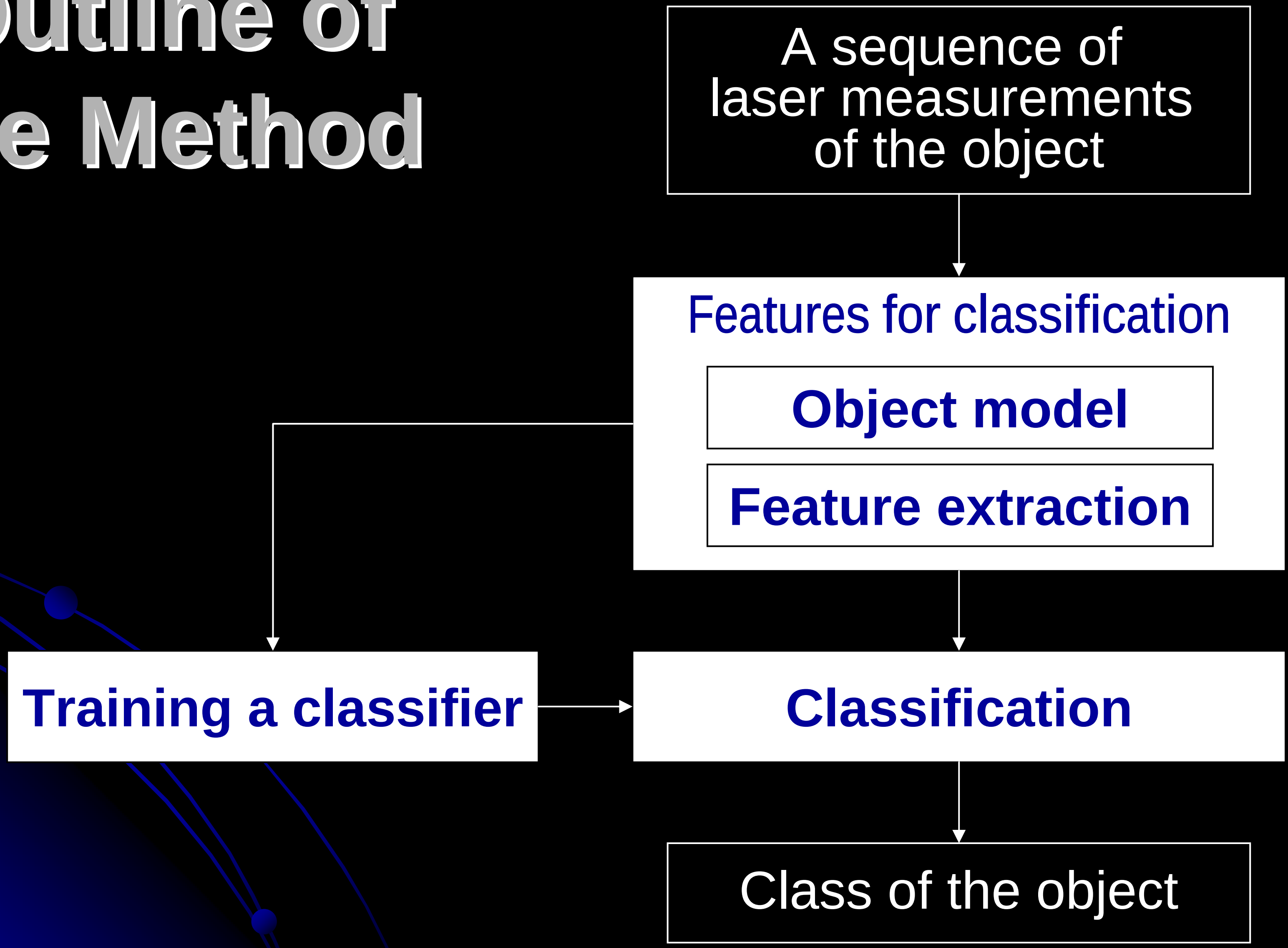
- **Input:**

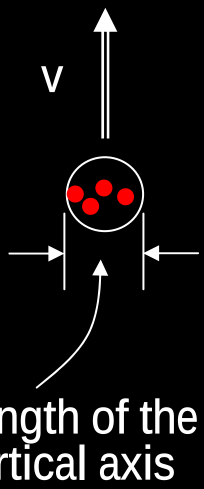
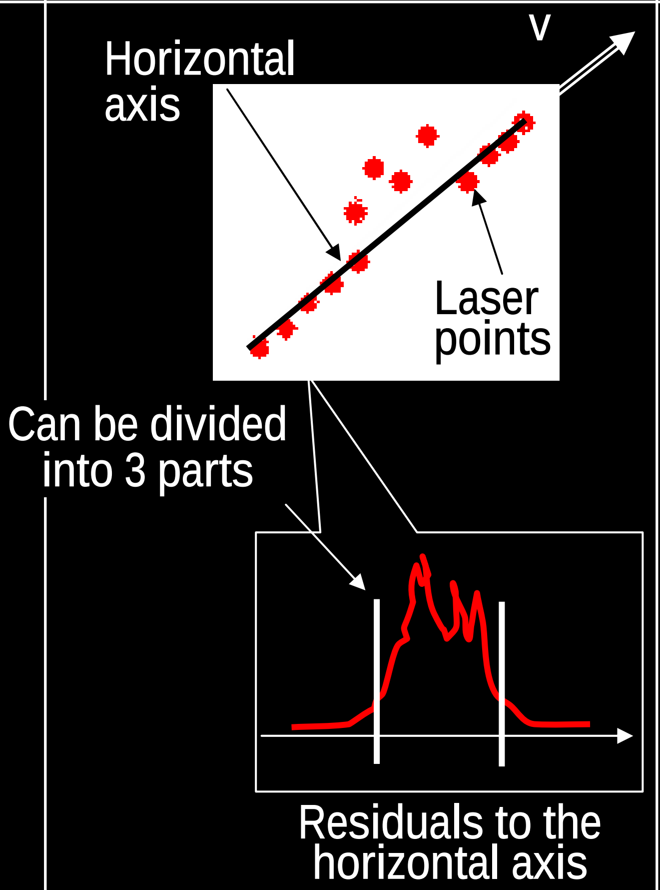
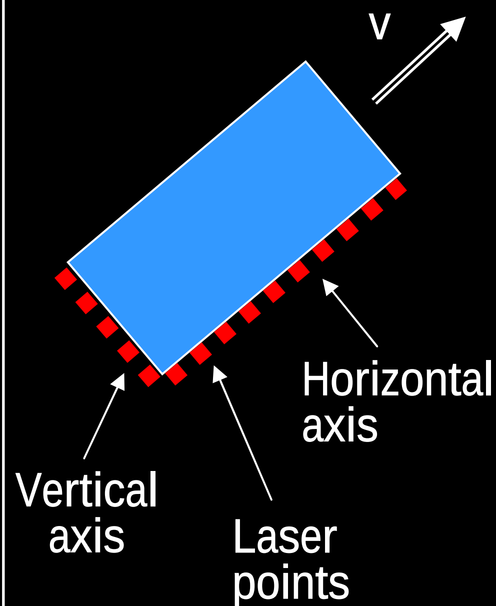
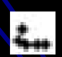
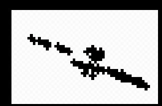
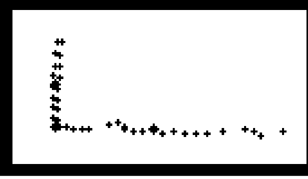
  the laser measurements of the object from time S to time K,

- **Output:**

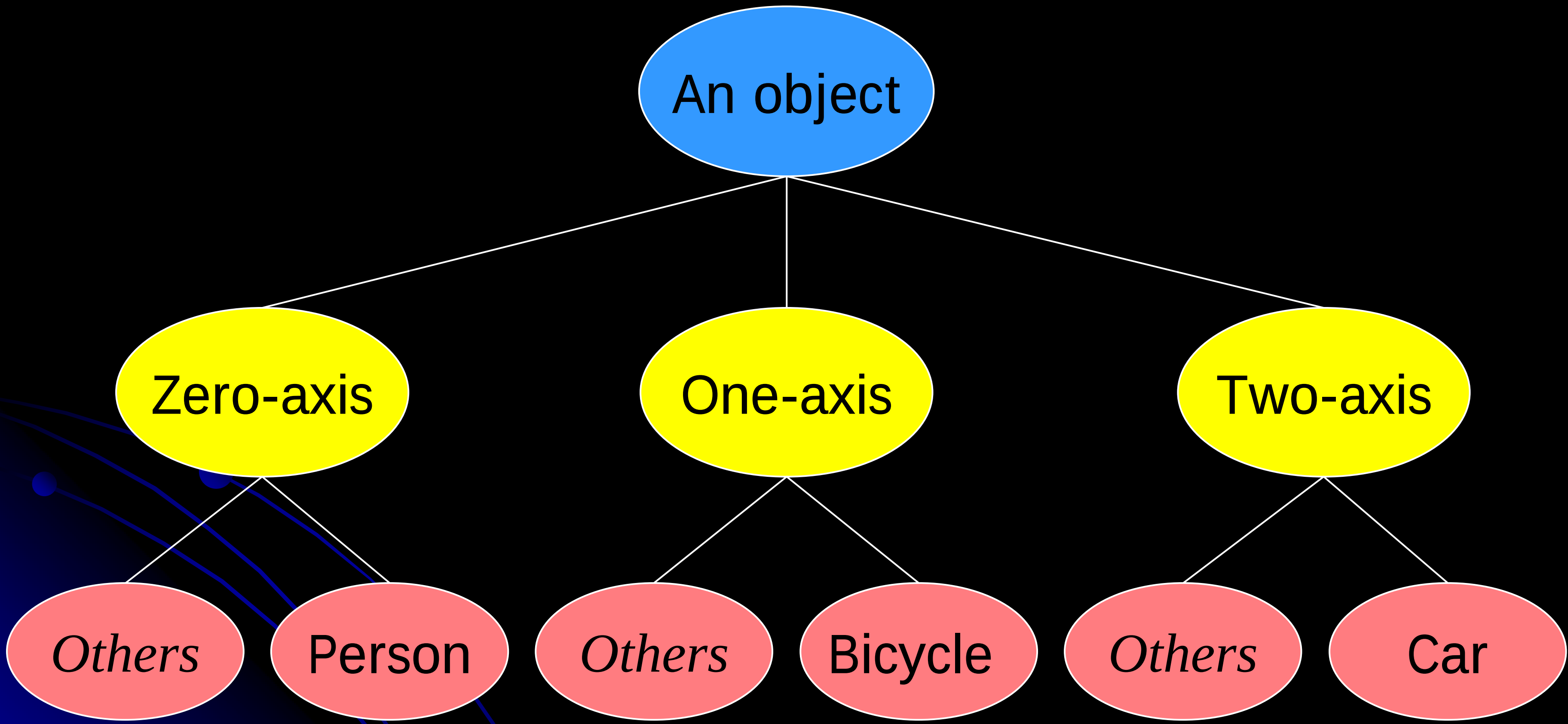
  Classify the object to be a single person, a group of people, a bicycle or a car.

Outline of the Method



	Person	Bicycle	Car
Model	 *v: motion vector*		
A real data			

Object Model

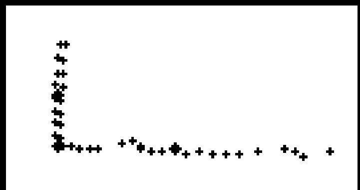


Object Model

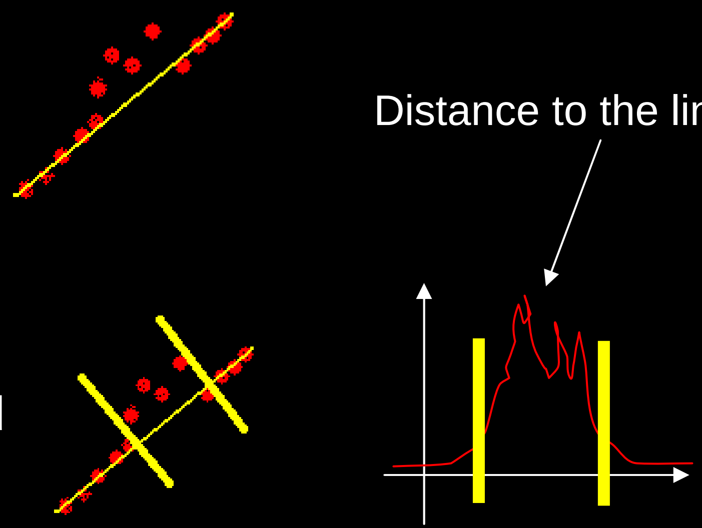
Car model :

Vertical side : Vertical to the vehicle's motion vector

Horizontal side : horizontal to the vehicle's motion vector



Bicycle model :



Represented by 3 parts

Feature Definition

Features of the stream

y_1	$\frac{1}{n \cdot \lVert\bar{v}\rVert} \sum_{k=1}^{n} \lVert v_k - \bar{v} \rVert$
y_2	$\frac{1}{n \cdot \lVert\bar{v}\rVert} \sum_{k=1}^{n} \lVert \bar{v}_k - \bar{v} \rVert$
y_3	$max\{l_k^{(v)}\}$
y_4	$max\{l_k^{(h)}\}$
y_5	$max\{l_k^{(d)}\}$

Speed variance (y_1, y_2)

Size of horizontal, vertical and diagonal sides (y_3–y_5)

Features at each instantaneous measurement

y_6	$\bar{v}_k$
y_7	$\frac{1}{m_v} \sum_{i=1}^{m_h} d_{ik}$
y_8	$\frac{1}{m_h} \sum_{i=1}^{m_v} d_{ik}$
y_9	$\frac{\bar{d}_k}{D_k}$

Speed (y_6)

Point fitting residual horizontal and vertical axis (y_7, y_8)

Residual of middle part / side parts (y_9)

Classification

Given a sequence of laser measurement of the object,

$$s = \{z_{k1}, ..., z_{kn}\}$$

Extract features $\{Y_1, ...Y_9\}$

Where, $Y_i = y_{i,k1}, ..., y_{i,kn}$

We find $c_j = \arg\max_j P(c_j | Y_1, ..., Y_9)$

Bays' rule $c_j = \arg\max_j \{P(c_j) \cdot \Pi_{i=0}^{9} P(Y_i | c_j)\}$

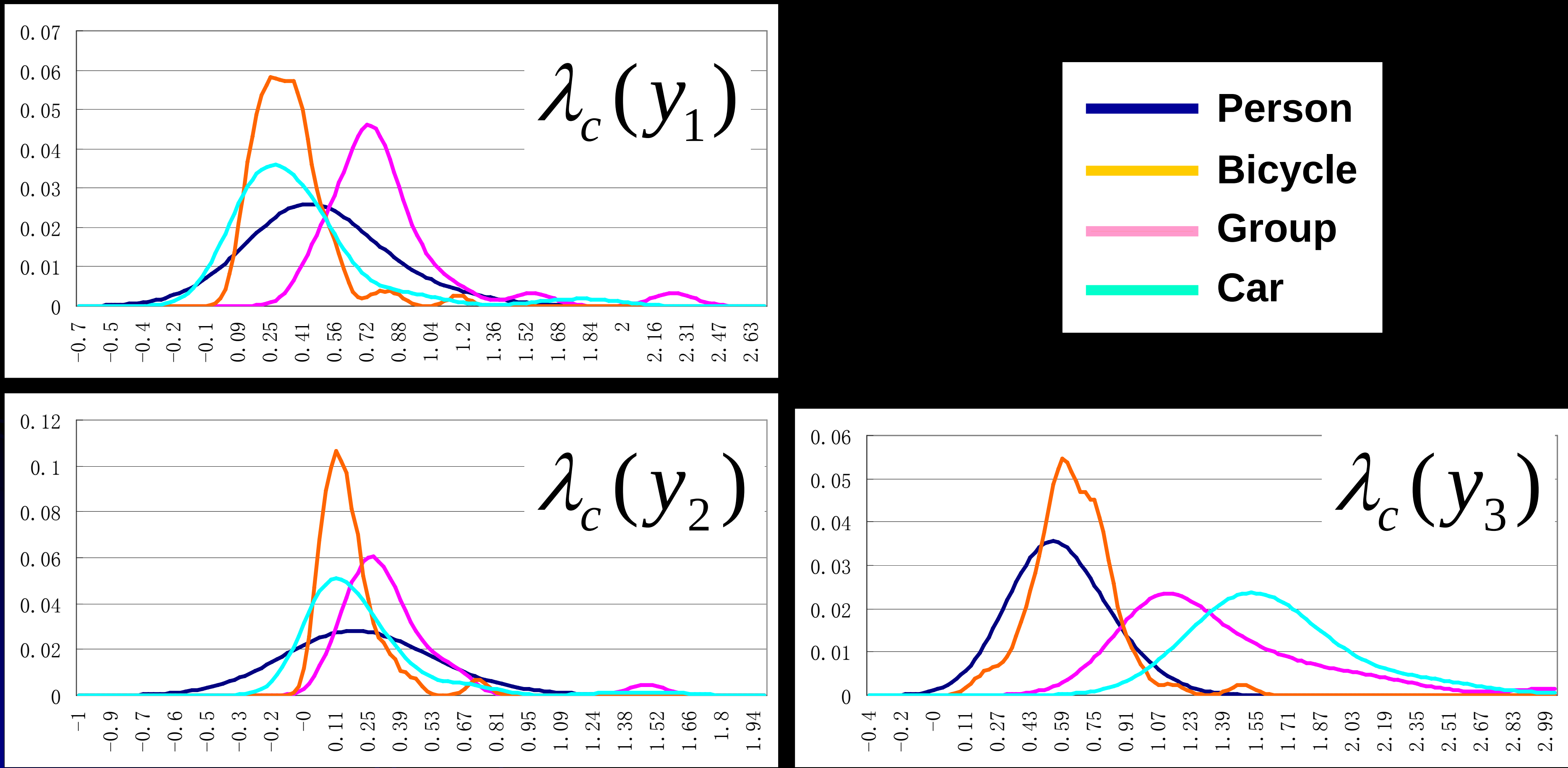
$$P(Y_i | c_j) = \sqrt[n]{P(y_{i,k1}, ..., y_{i,kn} | c_j)}$$

$$= \sqrt[n]{\Pi_{k=0}^{n} P(y_{i,k} | c_j)}$$

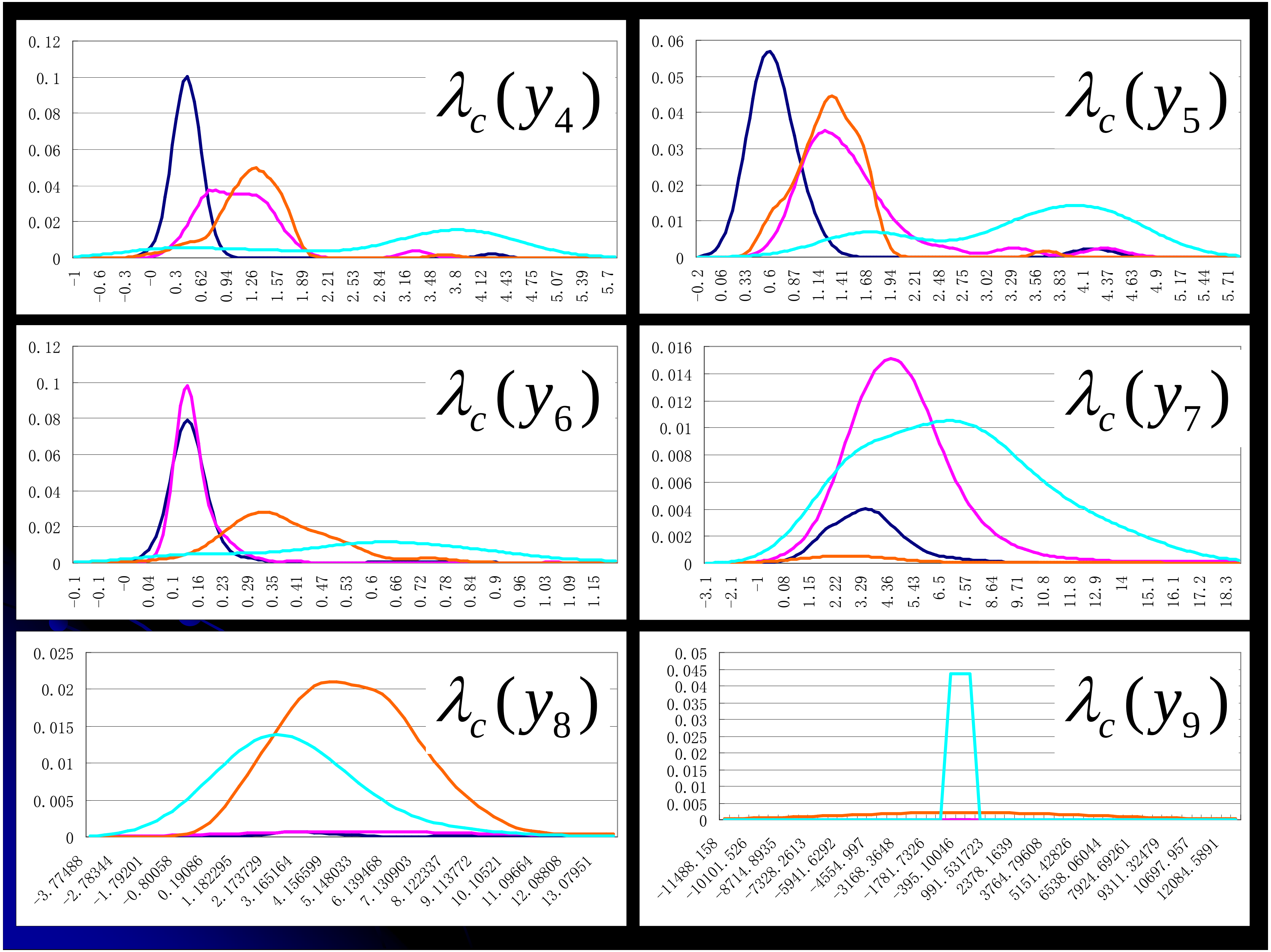
Training

$\lambda_{c_j}(y_i)$

The Likelihood Functions

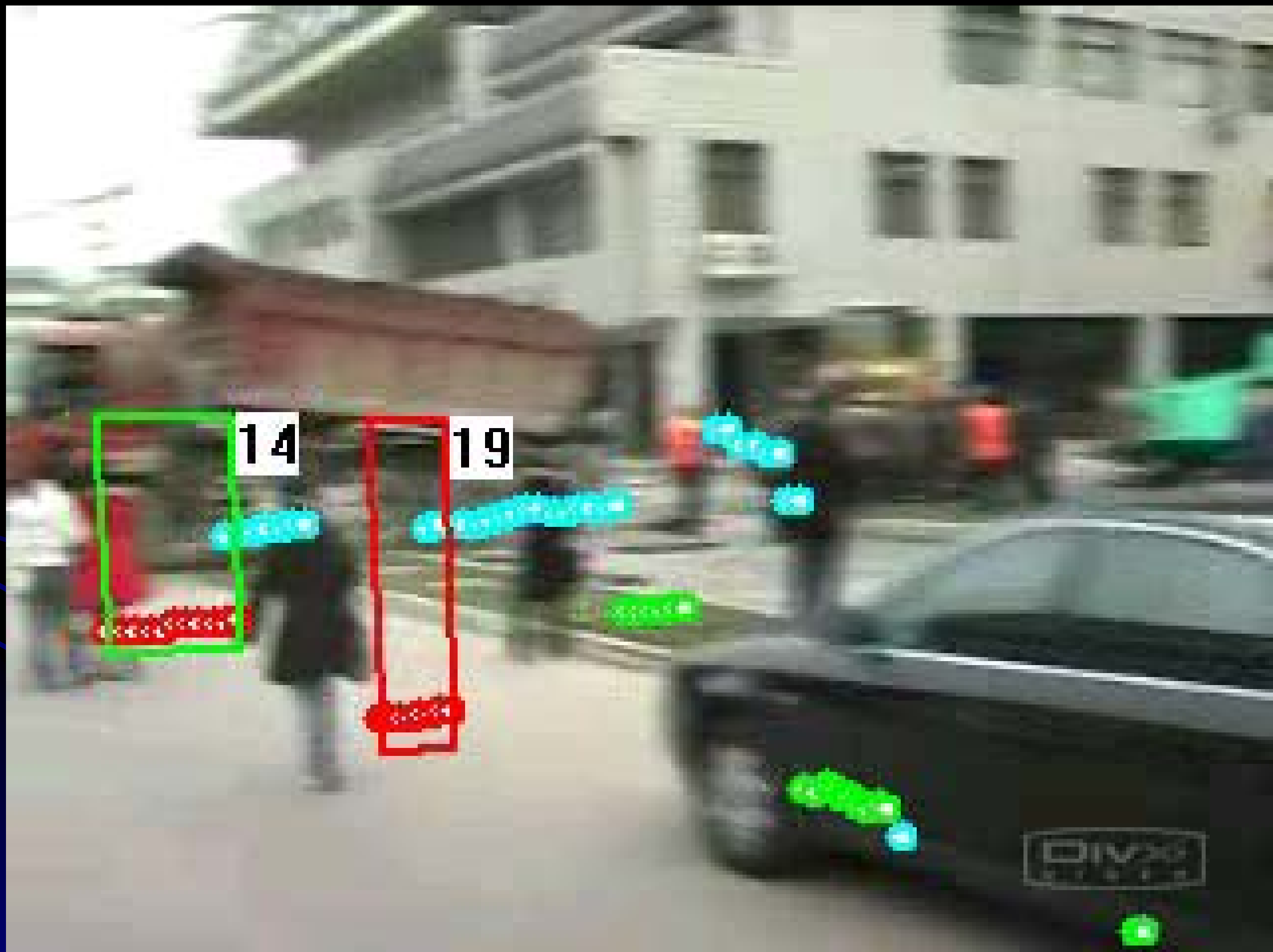


Normalized Histogram



λc(y4)
0. 12 0. 1 0. 08 0. 06 0. 04 0. 02 0
-1 -0.6 -0.3 -0 0.3 0.62 0.94 1.26 1.57 1.89 2.21 2.53 2.84 3.16 3.48 3.8 4.12 4.43 4.75 5.07 5.39 5.7
λc(y5)
0. 06 0. 05 0. 04 0. 03 0. 02 0. 01 0
-0.2 0.06 0.33 0.6 0.87 1.14 1.41 1.68 1.94 2.21 2.48 2.75 3.02 3.29 3.56 3.83 4.1 4.37 4.63 4.9 5.17 5.44 5.71
λc(y6)
0. 12 0. 1 0. 08 0. 06 0. 04 0. 02 0
-0.1 -0.1 -0 0.04 0.1 0.16 0.23 0.29 0.35 0.41 0.47 0.53 0.6 0.66 0.72 0.78 0.84 0.9 0.96 1.03 1.09 1.15
λc(y7)
0. 016 0. 014 0. 012 0. 01 0. 008 0. 006 0. 004 0. 002 0
-3.1 -2.1 -1 0.08 1.15 2.22 3.29 4.36 5.43 6.5 7.57 8.64 9.71 10.8 11.8 12.9 14 15.1 16.1 17.2 18.3
λc(y8)
0. 025 0. 02 0. 015 0. 01 0. 005 0
-3.77488 -2.78344 -1.79201 -0.80058 0.19086 1.182295 2.173729 3.165164 4.156599 5.148033 6.139468 7.130903 8.122337 9.113772 10.10521 11.09664 12.08808 13.07951
λc(y9)
0. 05 0. 045 0. 04 0. 035 0. 03 0. 025 0. 02 0. 015 0. 01 0. 005 0
-11488.158 -10101.526 -8714.8935 -7328.2613 -5941.6292 -4554.997 -3168.3648 -1781.7326 -395.10046 991.531723 2378.1639 3764.79608 5151.42826 6538.06044 7924.69261 9311.32479 10697.957 12084.5891

Experiment - 1



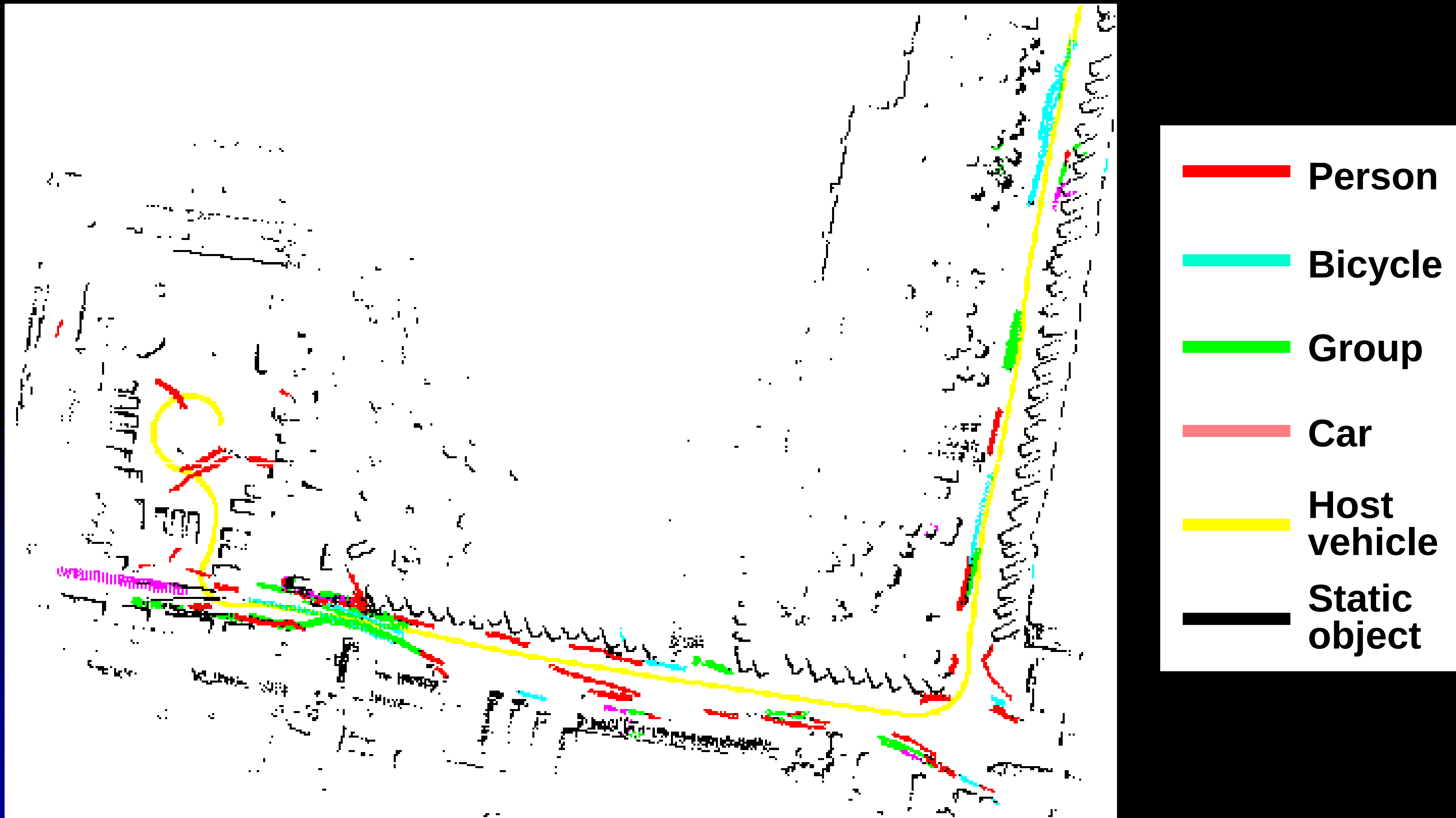
Objects

- person
- bicycle
- group
- car

Laser Points

- moving
- seed
- group

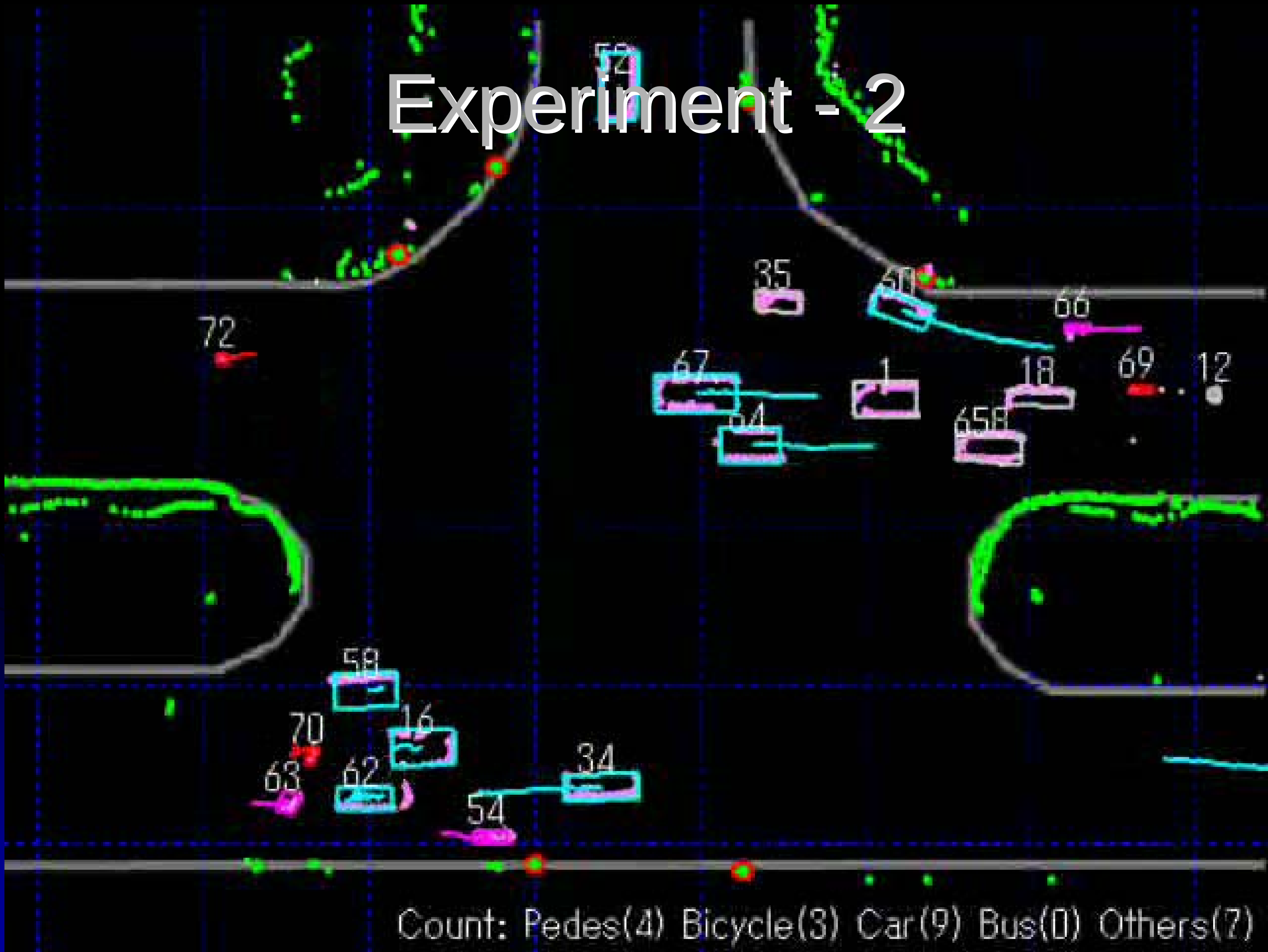
Map Generation

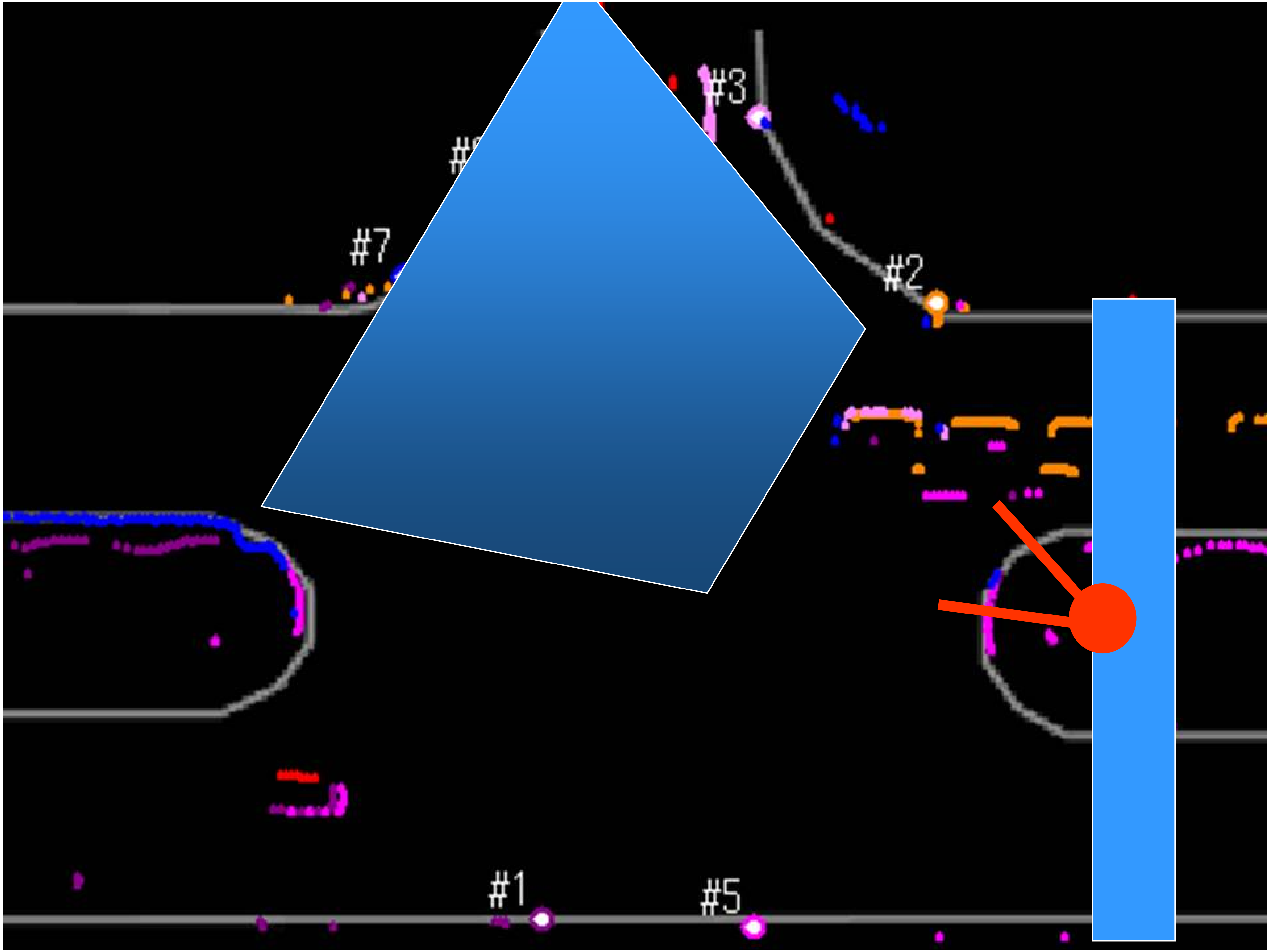


Classification Results

Class	Samples for Training	Samples for Test	Correct Classification	Accuracy Ratio
Person	44	14	13	93%
Group	22	7	6	86%
Bicycle	49	16	16	100%
Car	57	20	19	95%
Total	170	57	54	95%

Experiment - 2

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Experiment - 2

person bicycle car

Classification Results

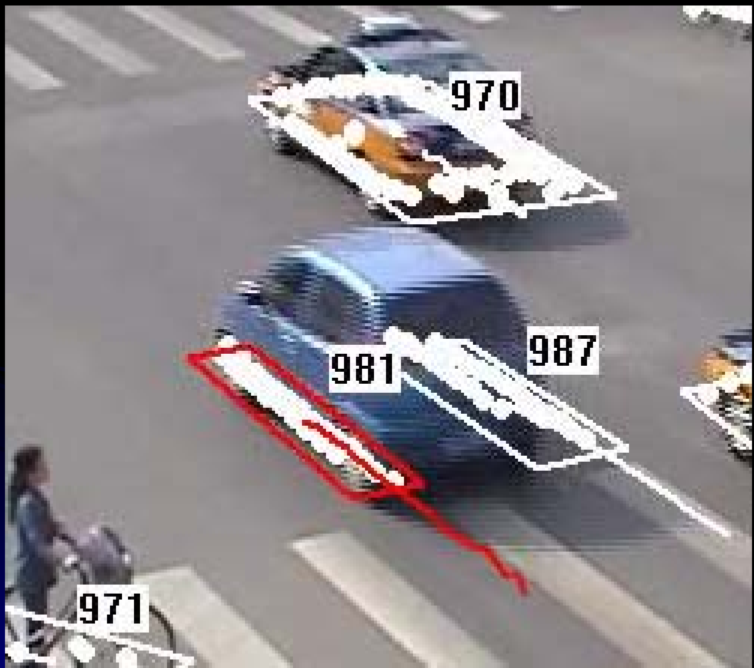
Training Sample

Person	11
Bicycle	39
Car	102

Examination

	Person	Bicycle	Car	Total	Accuracy
Person	26	3	2	31	83.9%
Bicycle	9	56	11	76	73.7%
Car	12	6	100	118	84.7%

Erroneous Classification



Conclusion and Future Work

- **A method is developed of classifying moving object, given a sequence of laser measurement.**
- **Major problem comes from erroneous tracking. A method of joint tracking and classification is to be developed.**

Thank You.

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