

# 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

GPS/INS

Laser

SLAM with Moving Object  
Detection and Tracking

Vehicle  
Pose

Map  
(static)

Moving  
Object

Observation  
(clusters)

Control  
Input

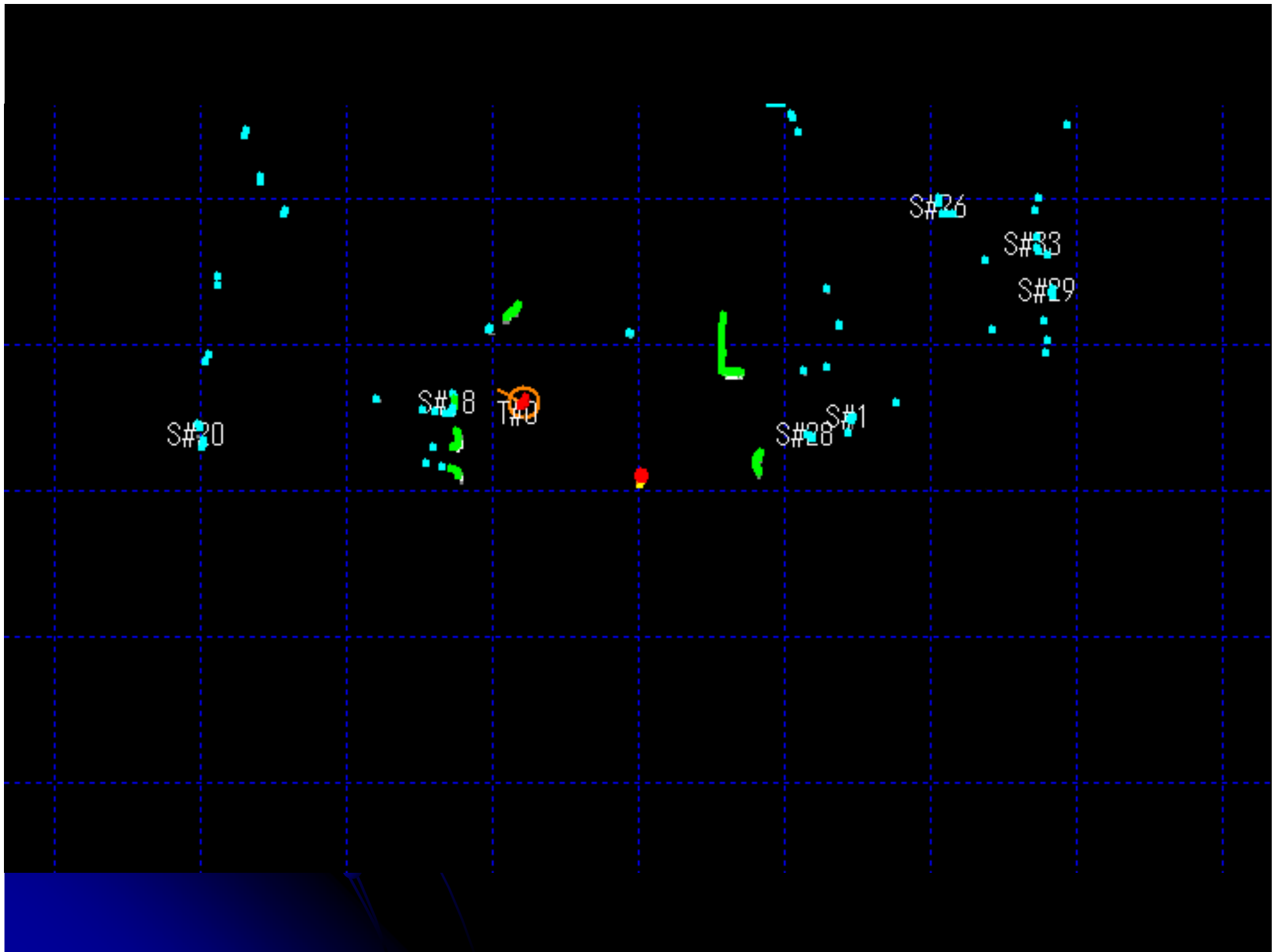
$$p(x_k, y_k, s_k, m | z_{0:k}, u_{0:k})$$

Vehicle  
pose

Moving  
object

Seed

Static object  
(map)





清华大学美术学院文化国际创新中心 - 伊士顿万里生展陈设计

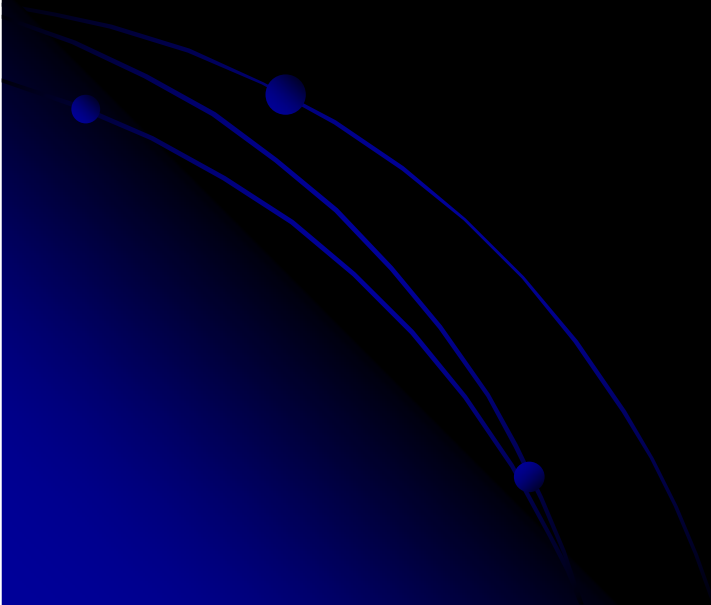
伊士顿万里生

# Needs from Platform 1

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

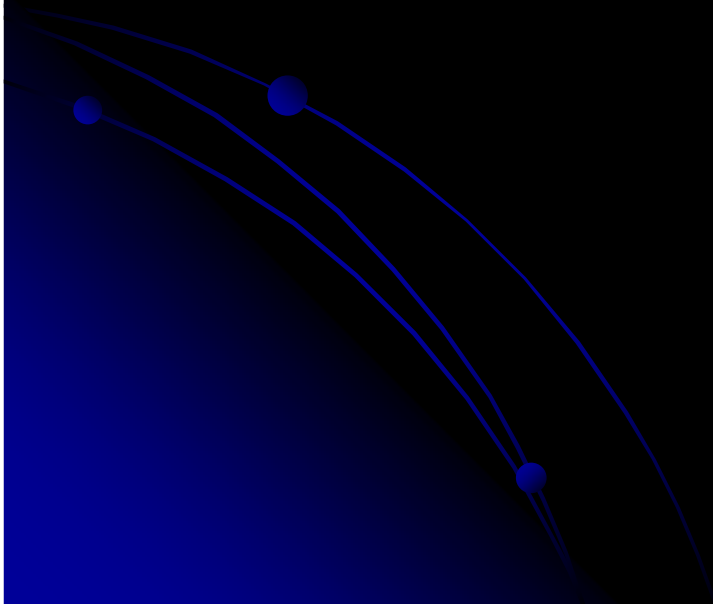
- **Input:**

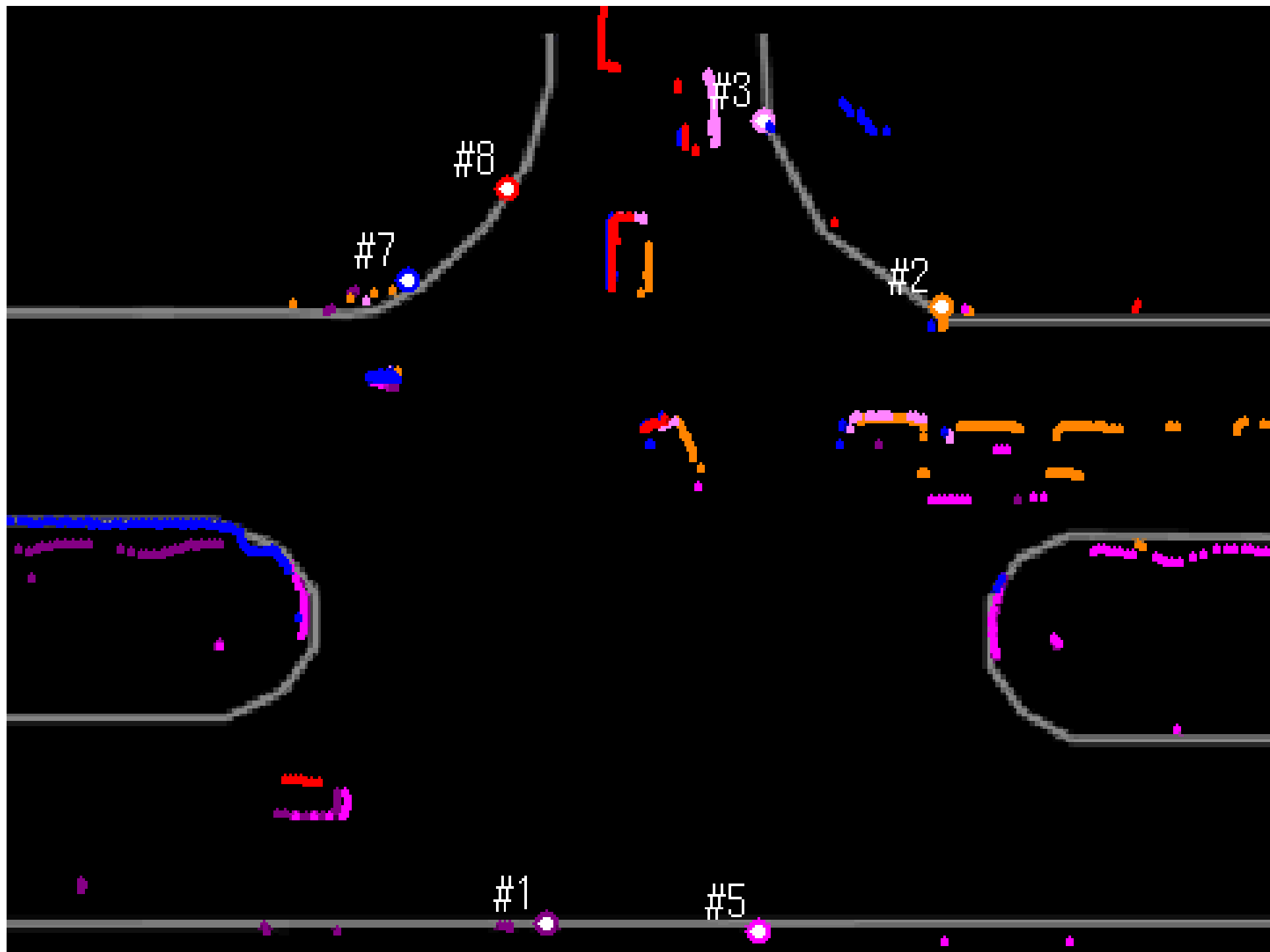
the laser measurements of the object from time  $S$





**Server PC**

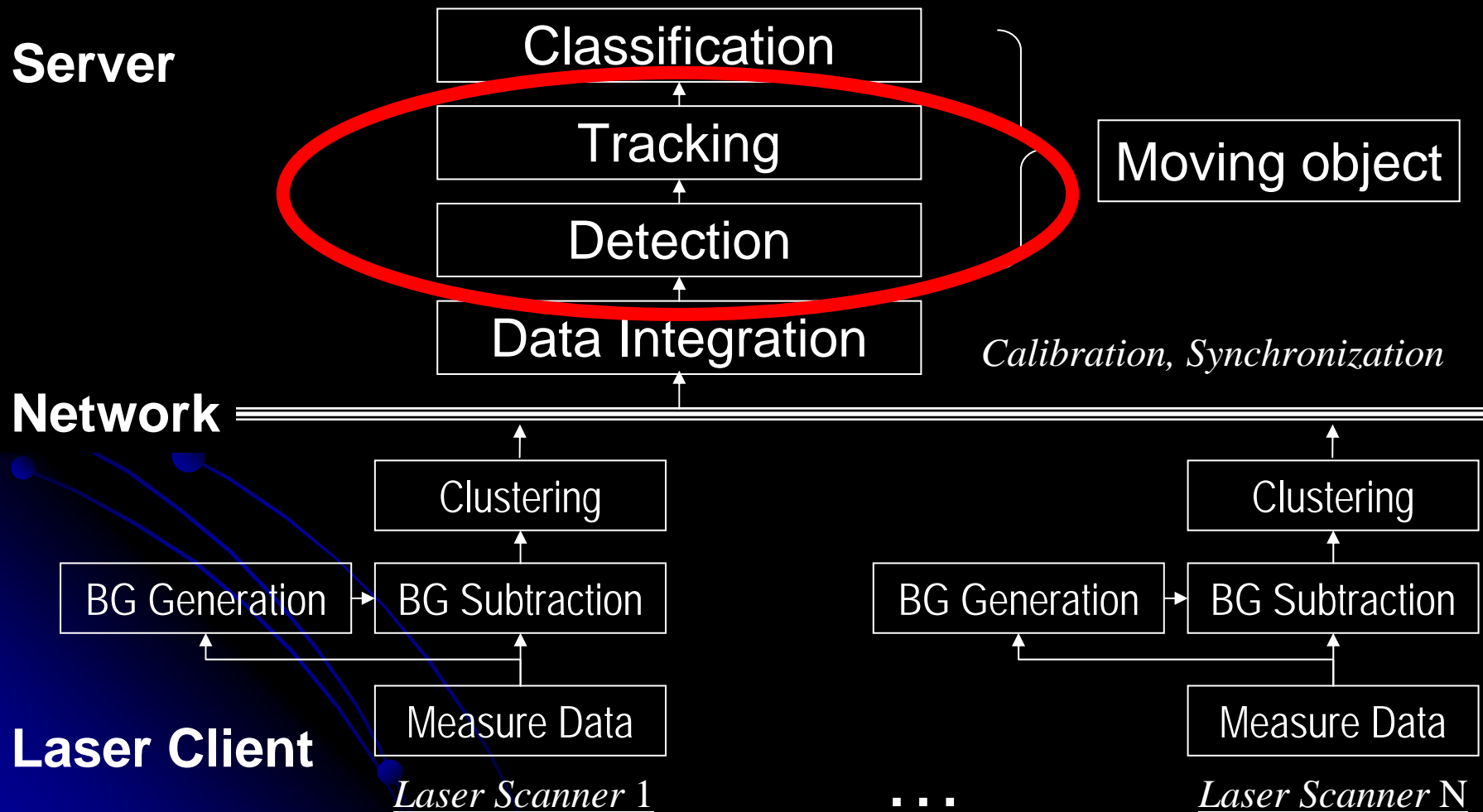








# Moving Object Detection and Tracking using a Network of Laser Scanners (ITSC08)



# Needs from Platform 2

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

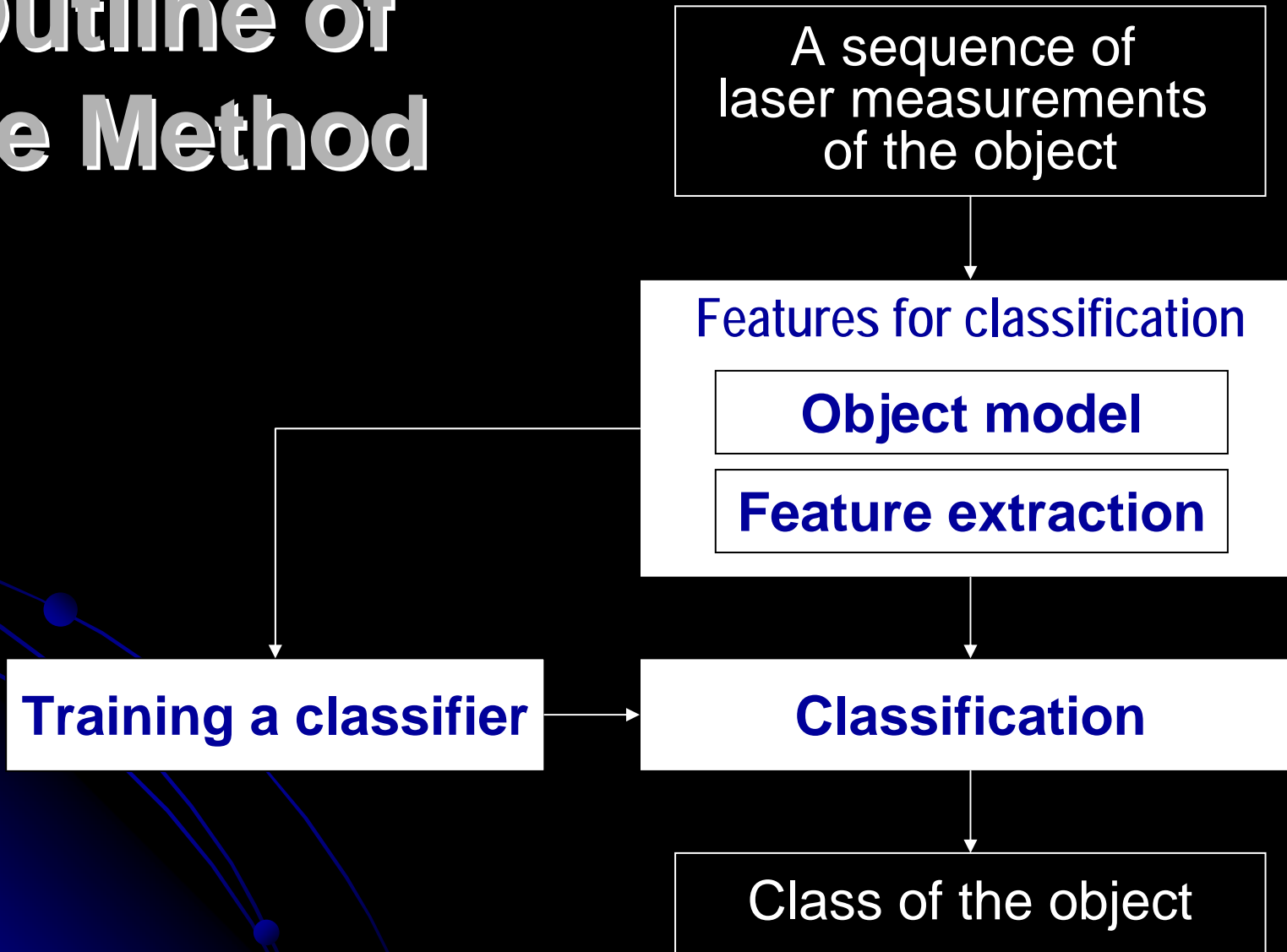
- **Input:**

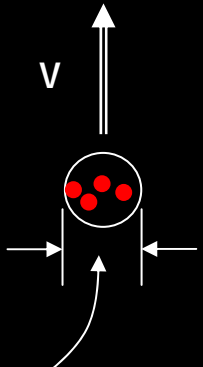
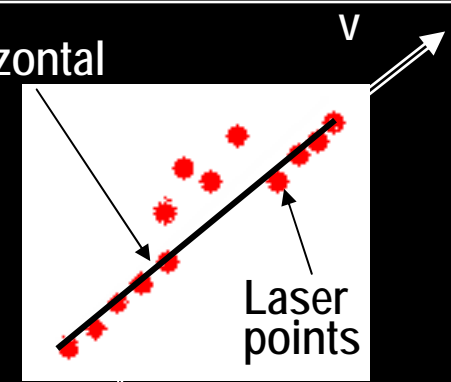
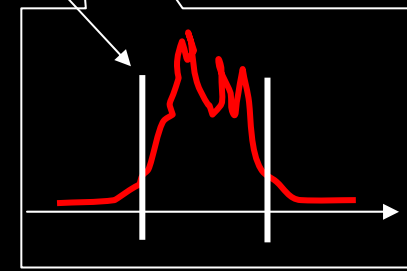
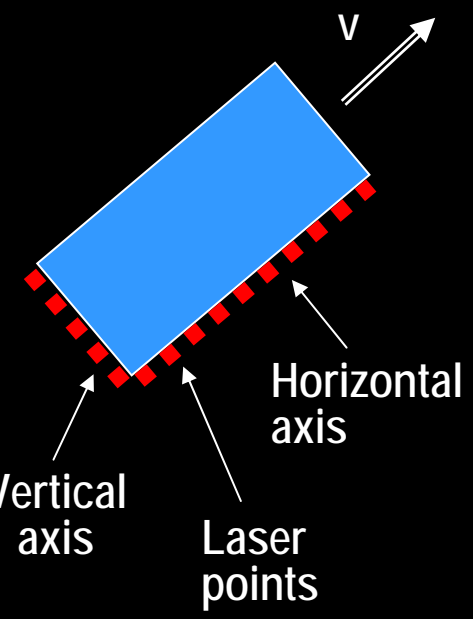



the laser measurements of the object from time  $S$  to time  $K$ ,

- **Output:**

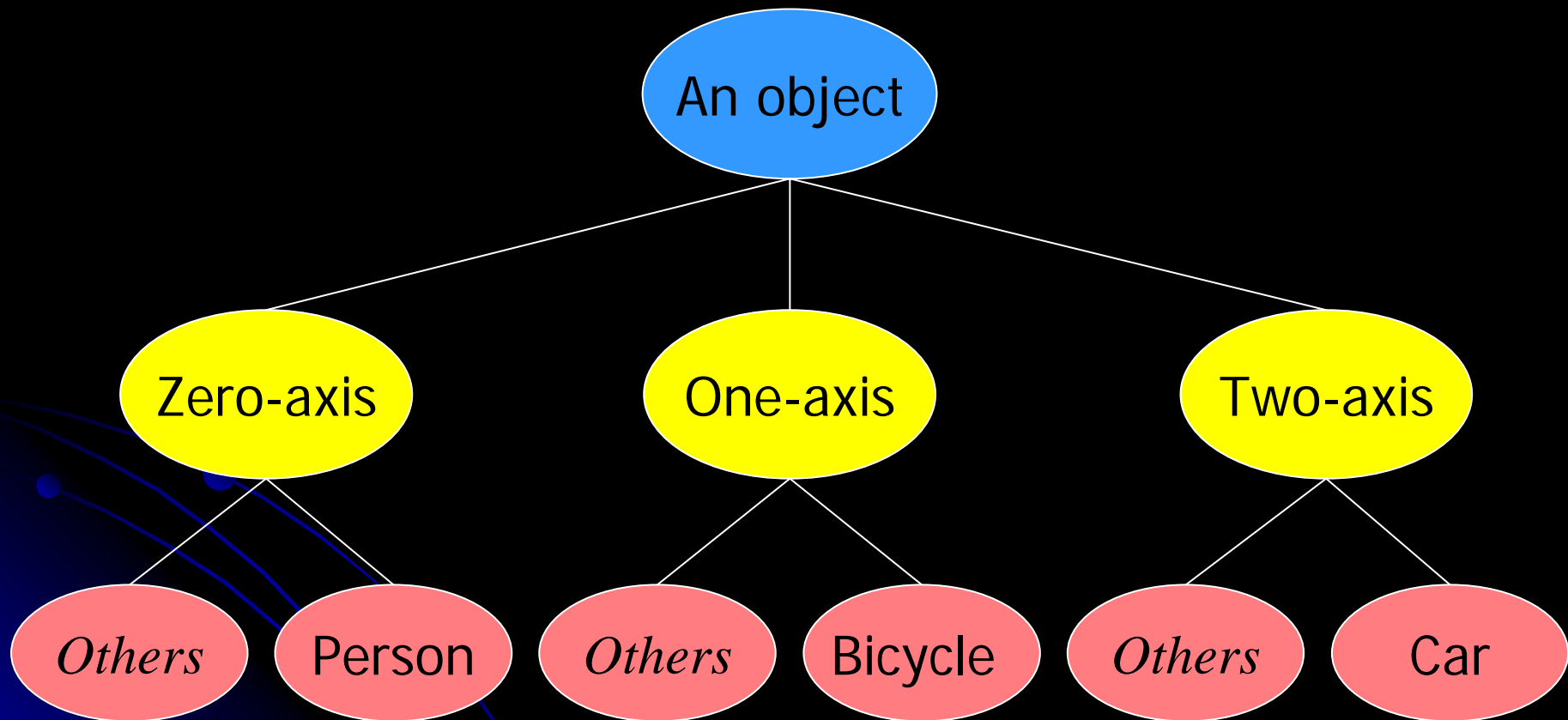
Classify the object to be a single person, a group of people, a bicycle or a car.

# Outline of the Method



	Person	Bicycle	Car
Model	 <p>Length of the vertical axis</p> <p><u>v: motion vector</u></p>	 <p>Horizontal axis</p> <p>Laser points</p> <p>Can be divided into 3 parts</p>  <p>Residuals to the horizontal axis</p>	 <p>Horizontal axis</p> <p>Laser points</p> <p>Vertical axis</p>
A real data			

# Object Model



# Object Model

## Car model :

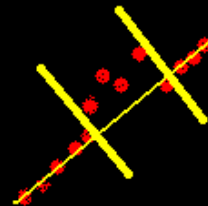
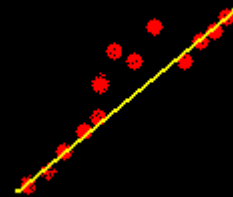
**Vertical side** : Vertical to the vehicle's motion vector

**Horizontal side** : horizontal to the vehicle's motion vector

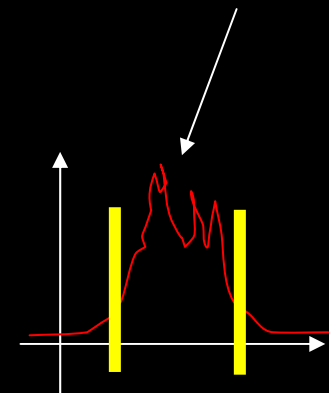


## Bicycle model :

Represented  
by 3 parts



Distance to the line



# Feature Definition

## Features of the stream

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

Speed variance

Size of horizontal,  
vertical and  
diagonal sides

## 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

Point fitting  
residual horizontal  
and vertical axis

Residual of middle  
part / side parts



# Classification

Given a sequence of laser measurement of the object,

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

Extract features

$$\{Y_1, \dots, Y_9\}$$

Where,

$$Y_i = y_{i,k1}, \dots, y_{i,kn}$$

We find

$$c_j = \arg \max_j P(c_j | Y_1, \dots, Y_9)$$

Bays' rule

$$c_j = \arg \max_j \{P(c_j) \cdot \prod_{i=1}^9 P(Y_i | c_j)\}$$

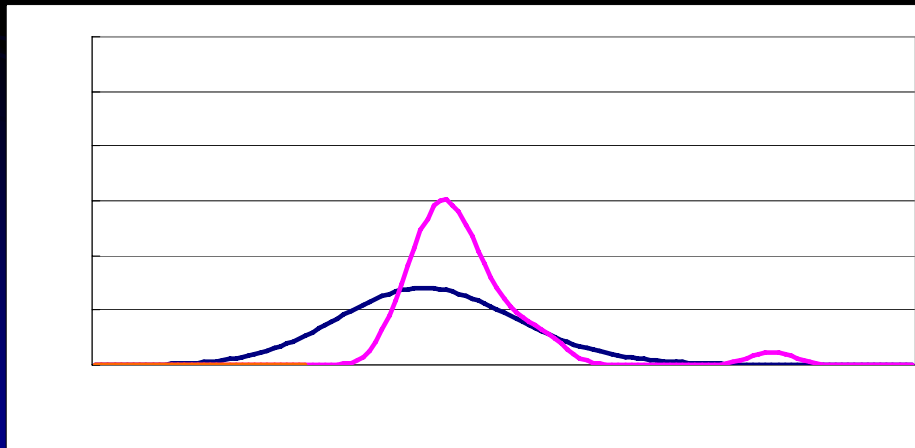
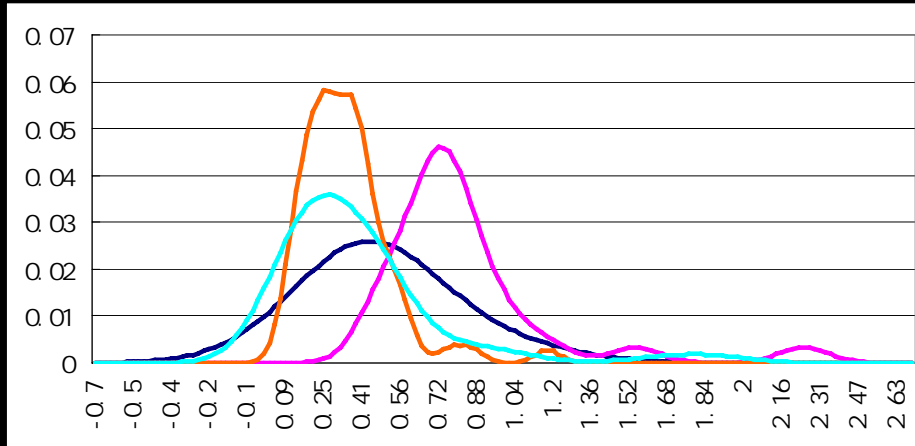
$$P(Y_i | c_j) = \sqrt[n]{P(y_{i,k1}, \dots, y_{i,kn} | c_j)}$$

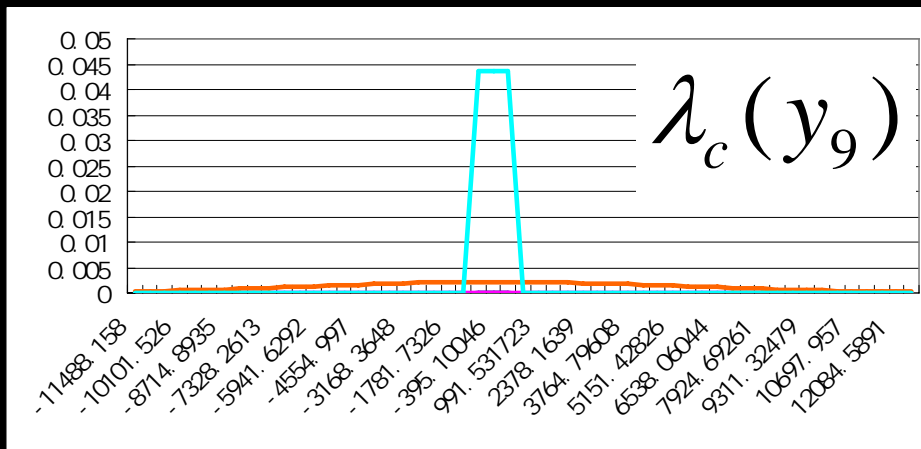
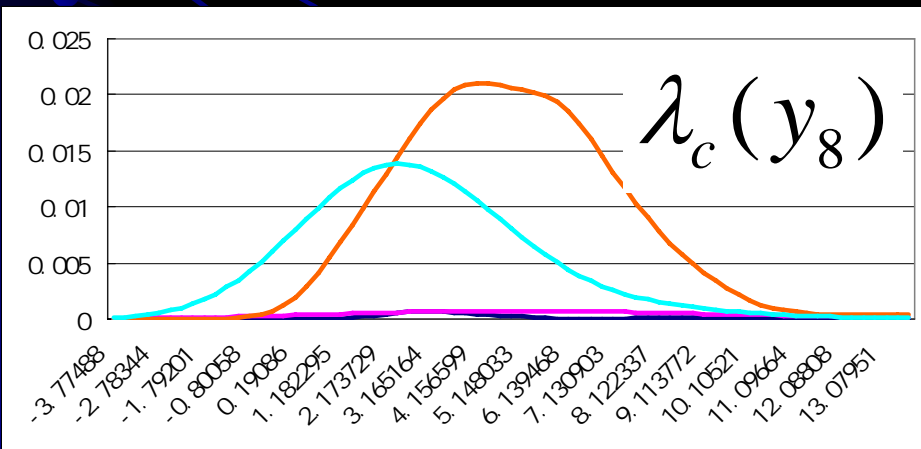
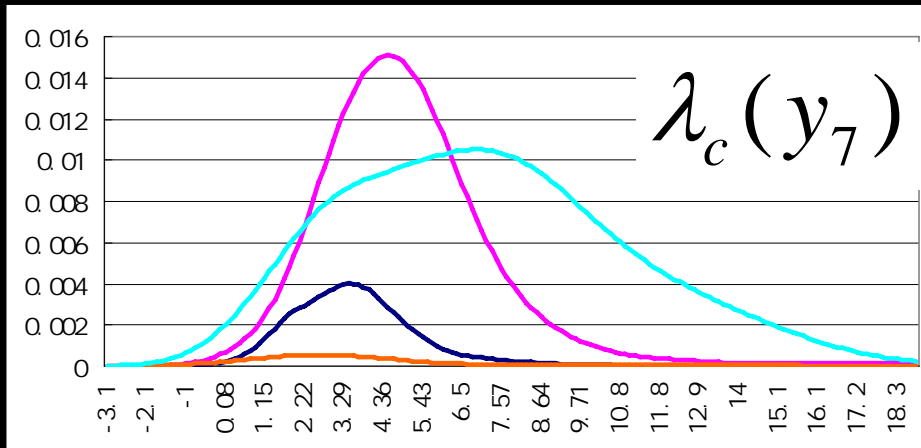
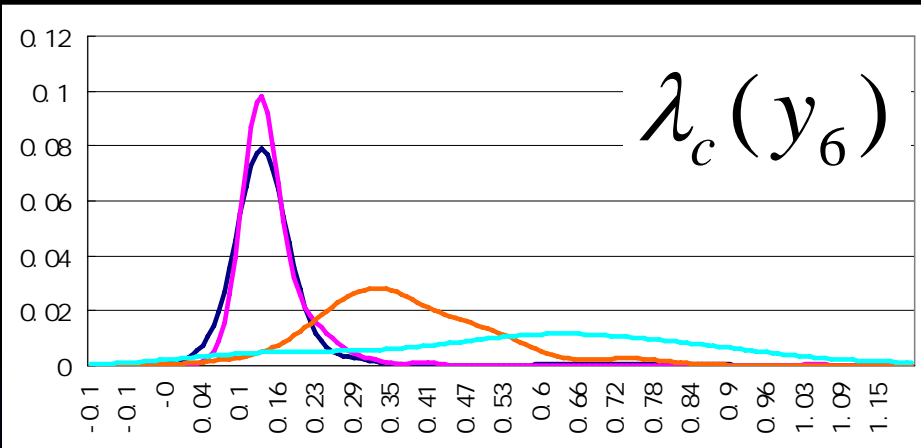
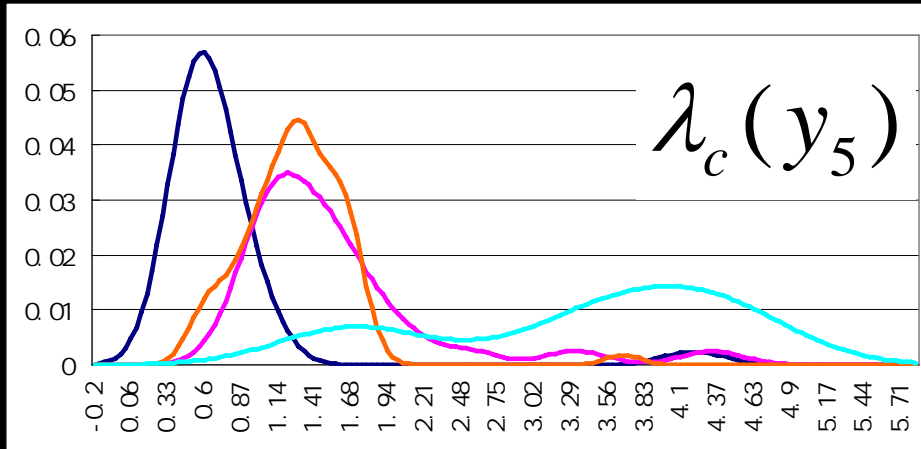
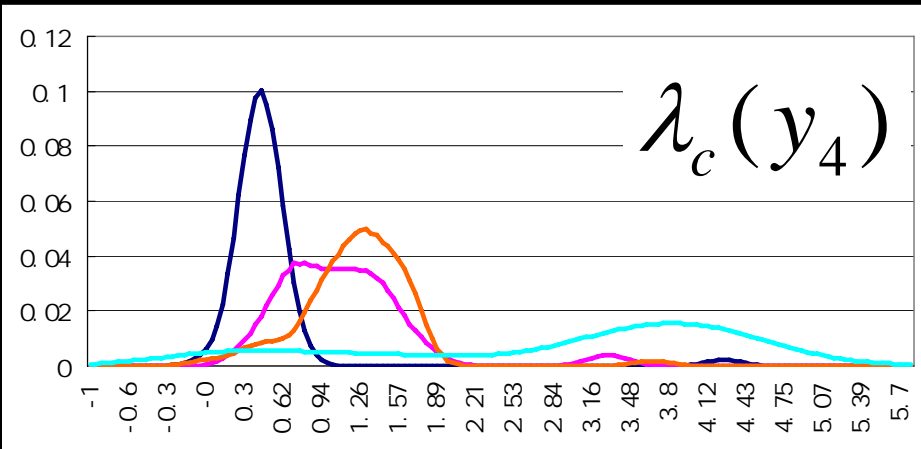
$$= \sqrt[n]{\prod_{k=1}^n P(y_{i,k} | c_j)}$$

Training

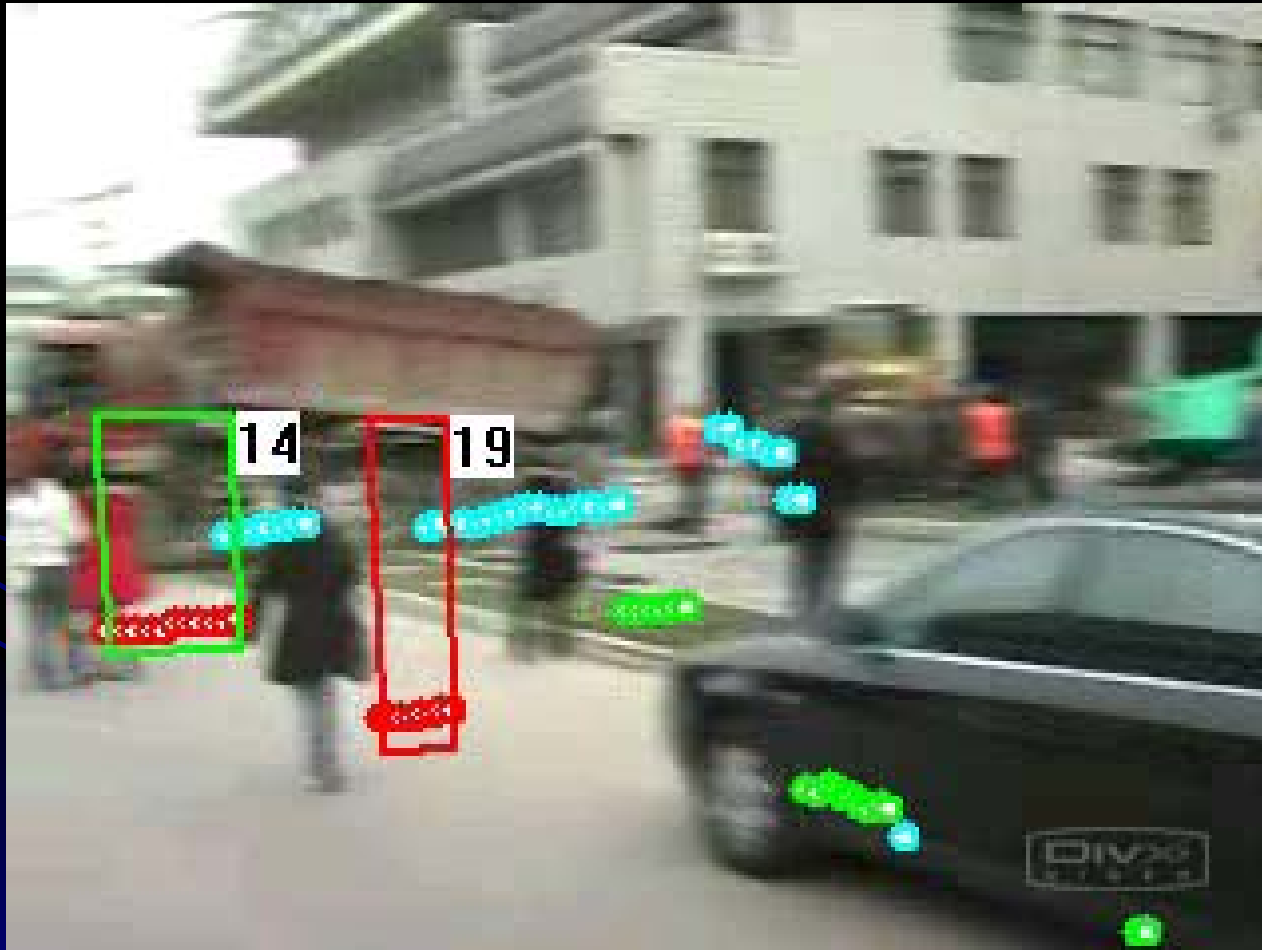
$$\lambda_{c_j}(y_i)$$

# The Likelihood Functions





# Experiment - 1



## Objects

 person

 bicycle

 group

 car

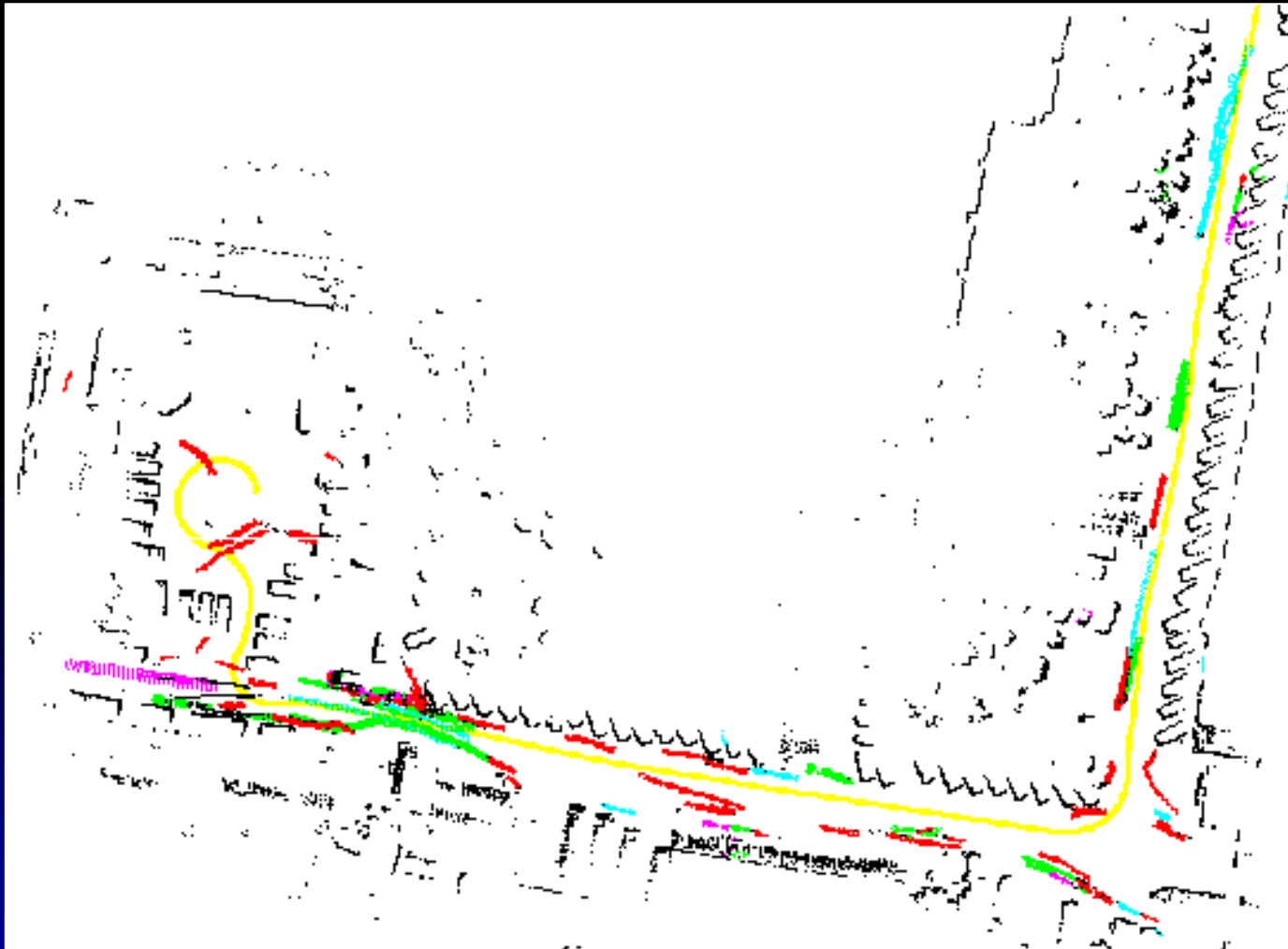
## Laser Points

 moving

 seed

 group

# Map Generation



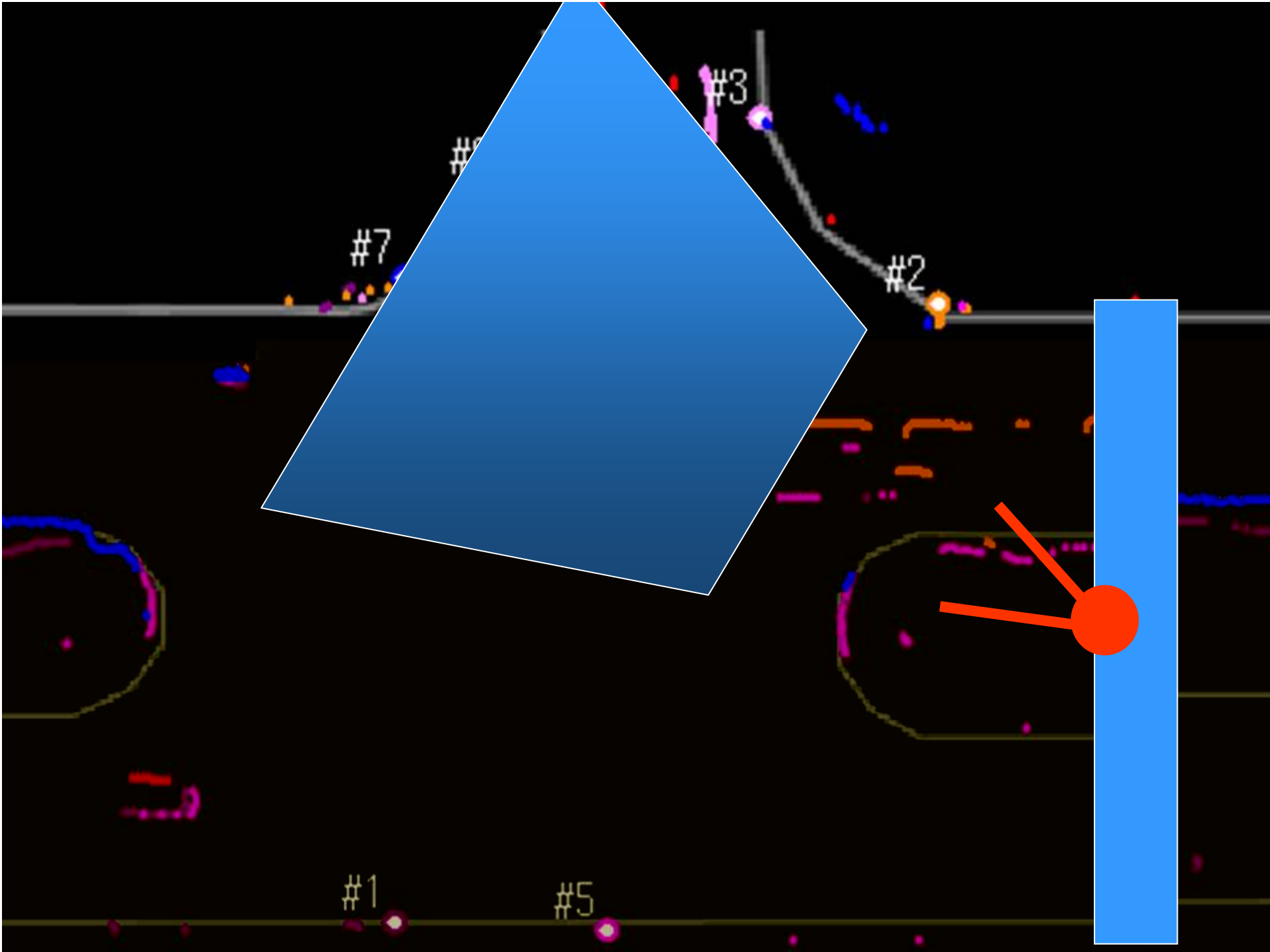
- Person**
- Bicycle**
- Group**
- Car**
- Host vehicle**
- Static object**

# Classification Results

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

# Experiment - 2







# Experiment - 2



person

bicycle

car

# Classification Results

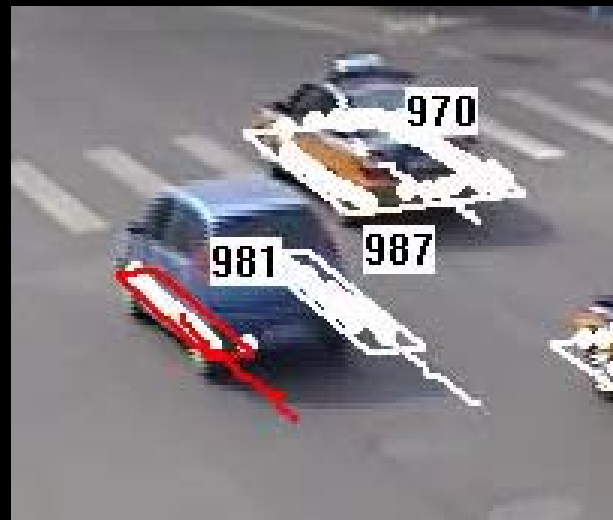
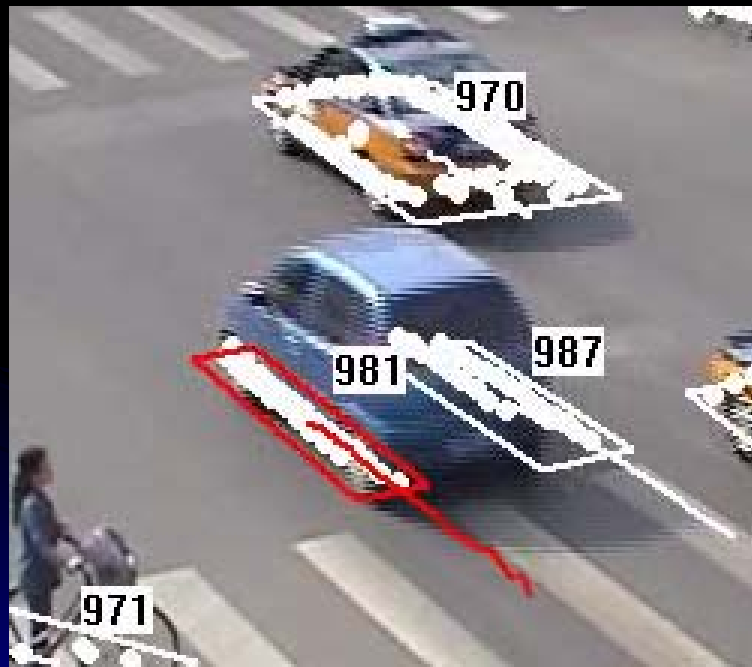
## Training Sample

Person	11
Bicycle	39
Car	102

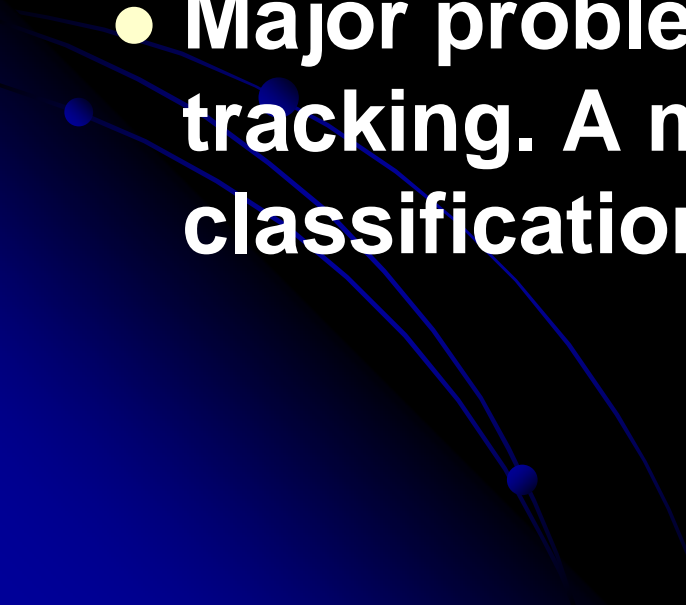
## Examination

	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.**
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# Thank You.

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