Zhao, H., et al., Detection and Tracking of Moving Objects at Intersections using a Network of Laser Scanners, IEEE Trans. ITS, vol. 13, no.2, 655-670, 2012.

MONITORING AN INTERSECTION USING A NETWORK OF LASER SCANNERS

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Background (1)

Analyzing and Monitoring the traffic behavior in an intersection

- Efficiently and accurately COLLECTING the TRAFFIC DATA in an INTERSECTION

- Real-timely DETECTING DANGEOUS SITUATIONS.

Background (2)

- Vision-based methods suffer mainly on the following difficulties
  - Occlusion
  - Computation Cost
  - Illumination Change

e.g. the camera is required to be set on a tall position, monitoring intersection from the above

To solve the problems

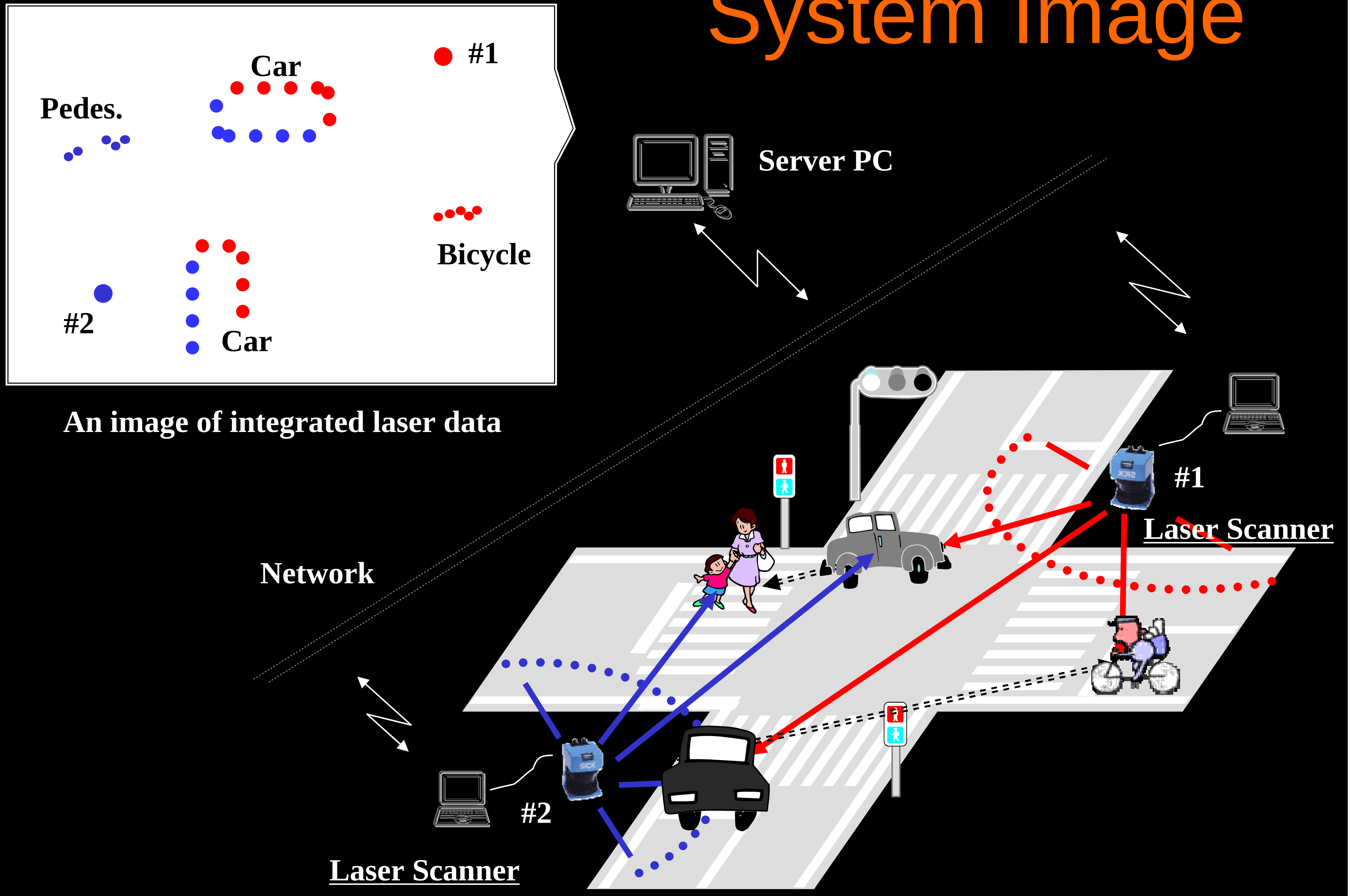
1. Restrict camera's setting conditi
2. Target on a simplified situation

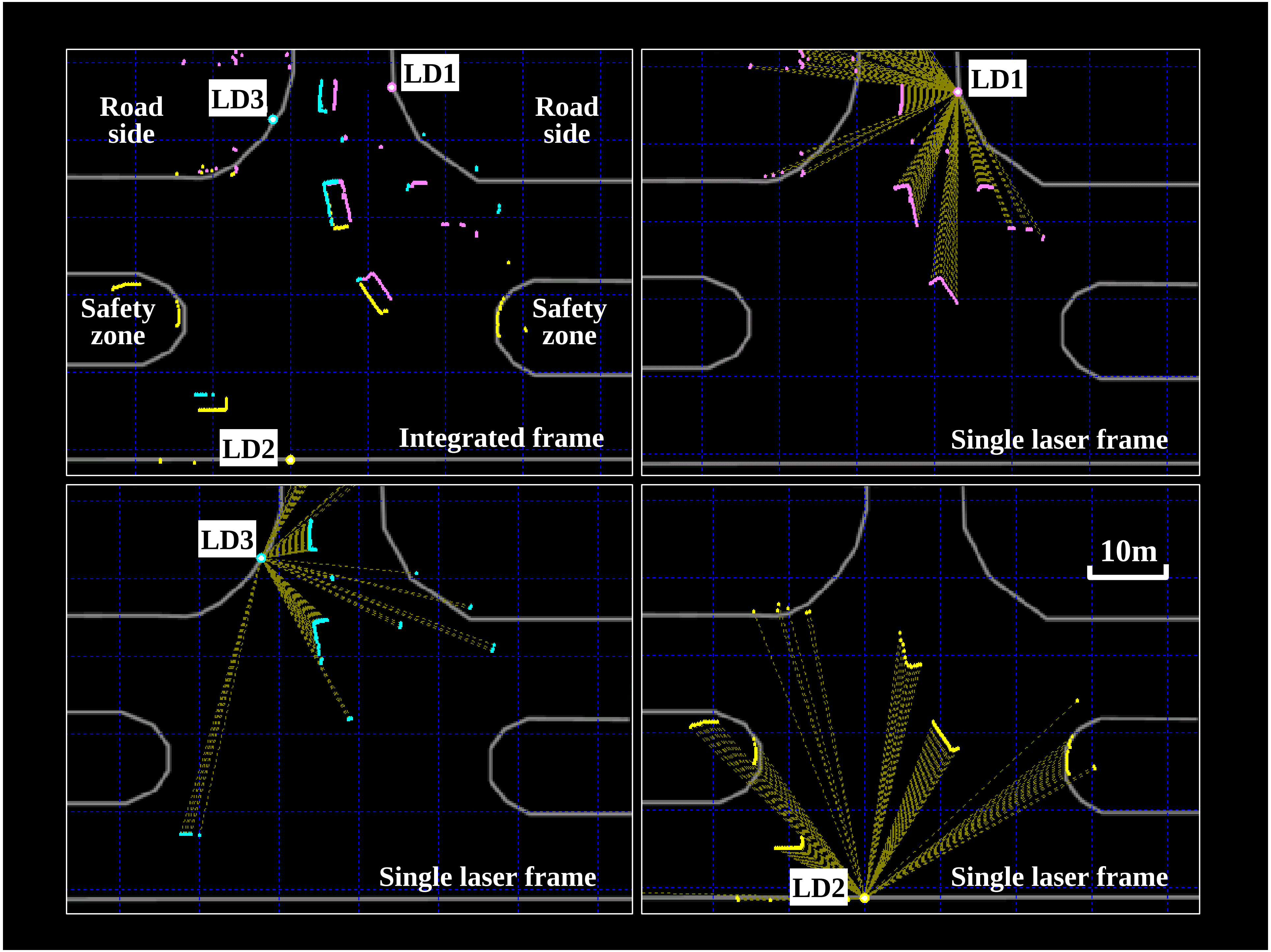
e.g. monitor vehicles of limited lanes, do not discriminate moving objects.

Objective

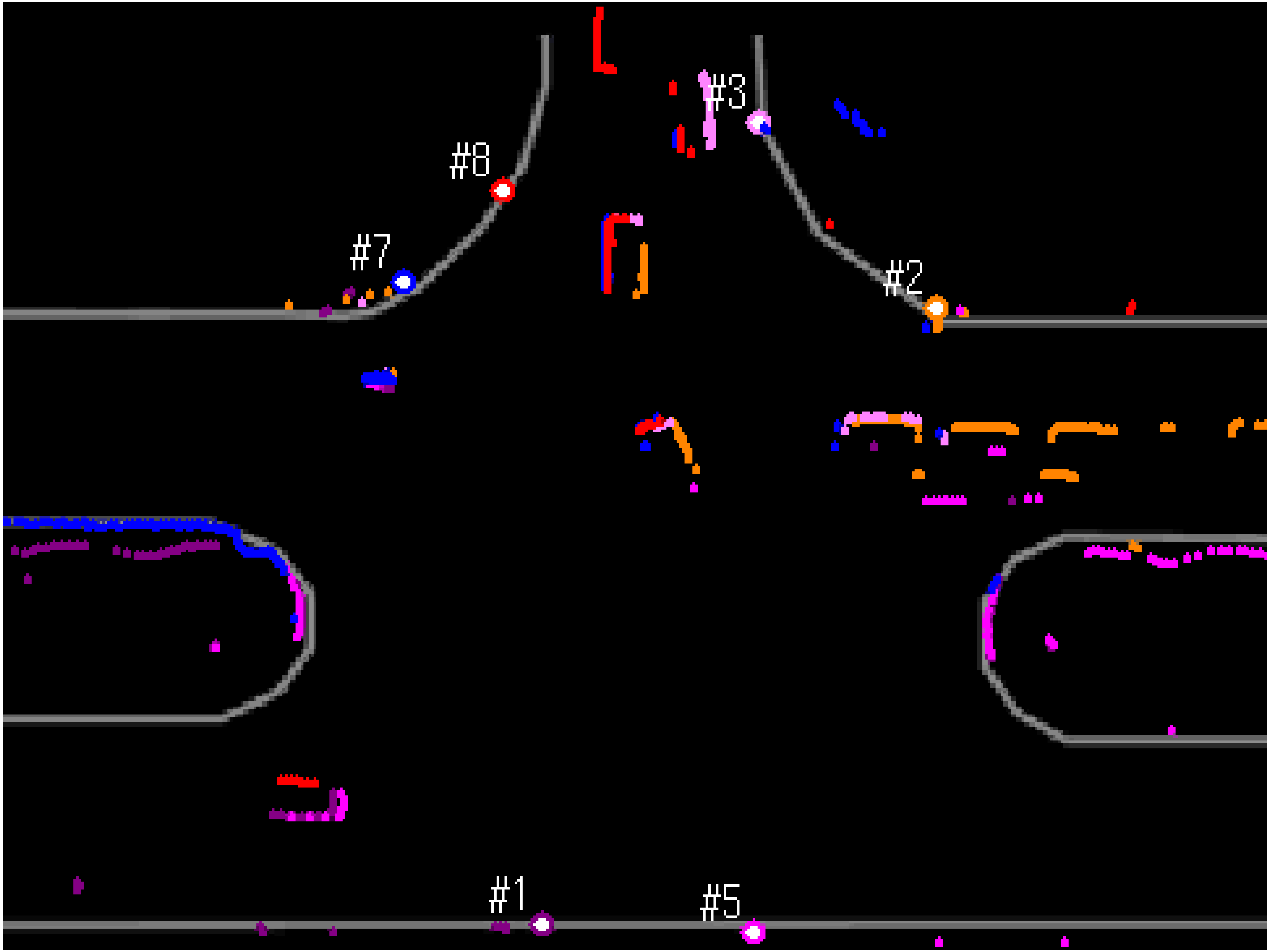
This research propose a novel system for monitoring and collecting **detailed traffic data**, with **easy setting condition**, in an environment of complicated traffic behavior, such as **intersection**, using **a network of single-row laser scanner.**

System Image

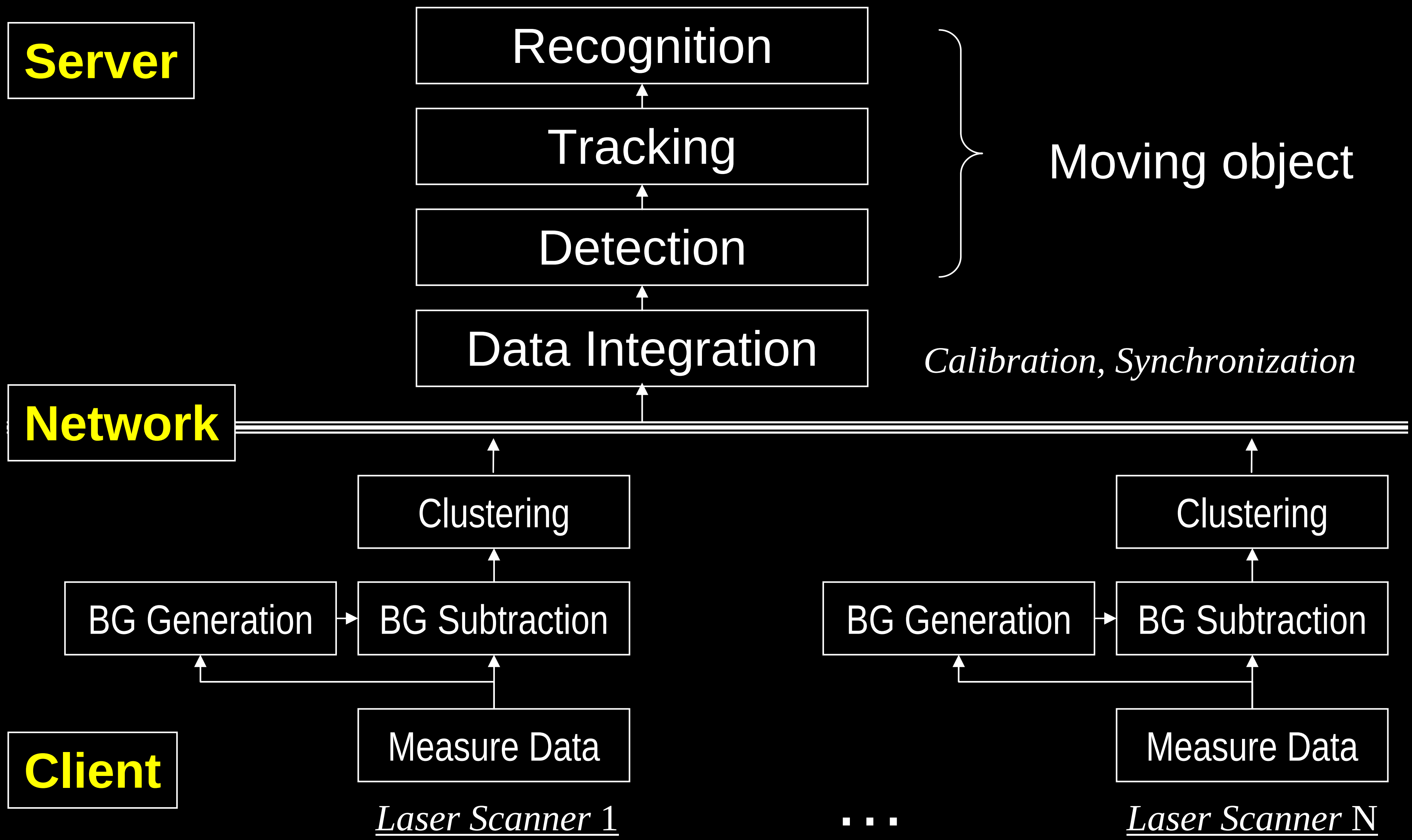


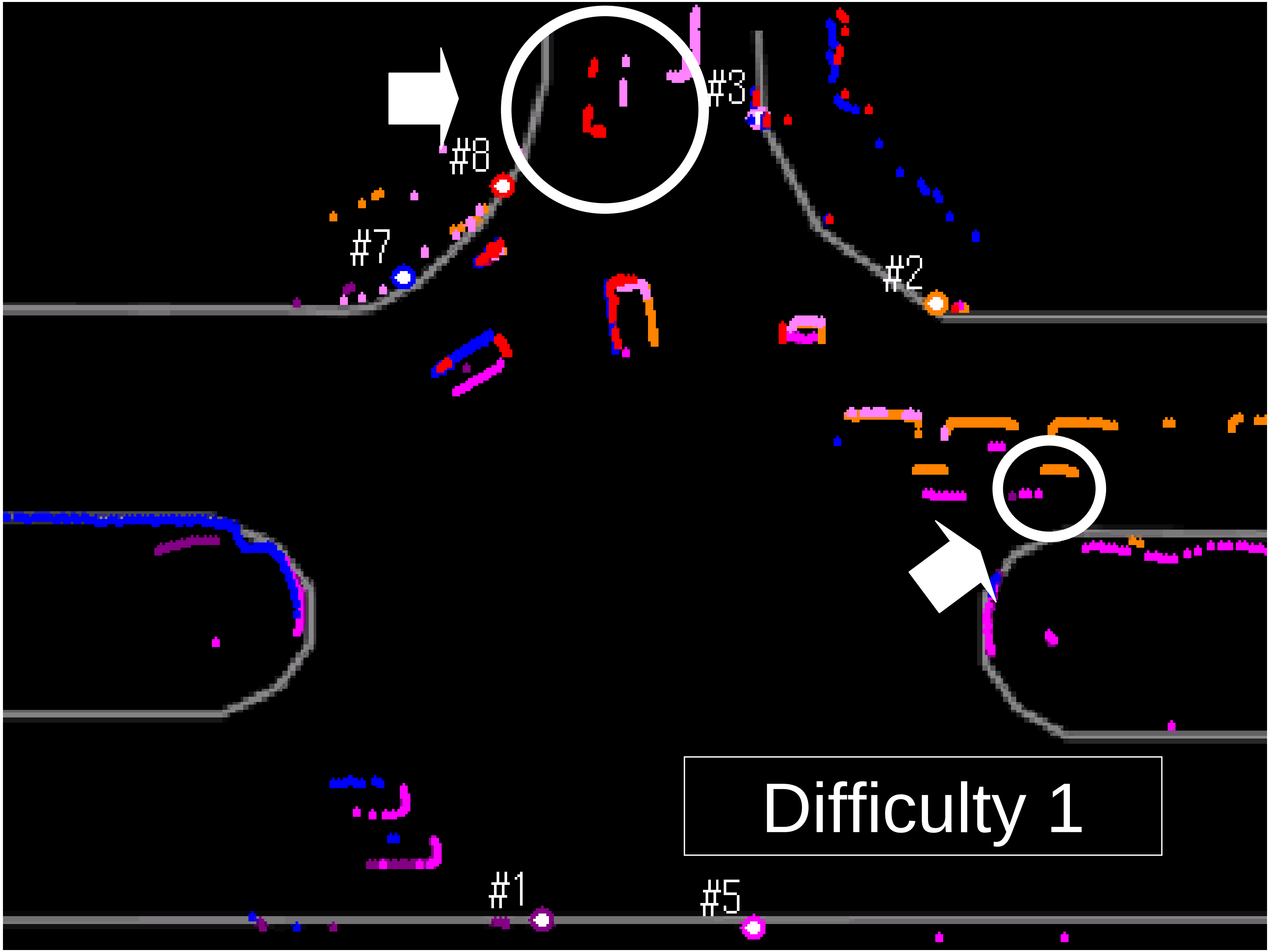


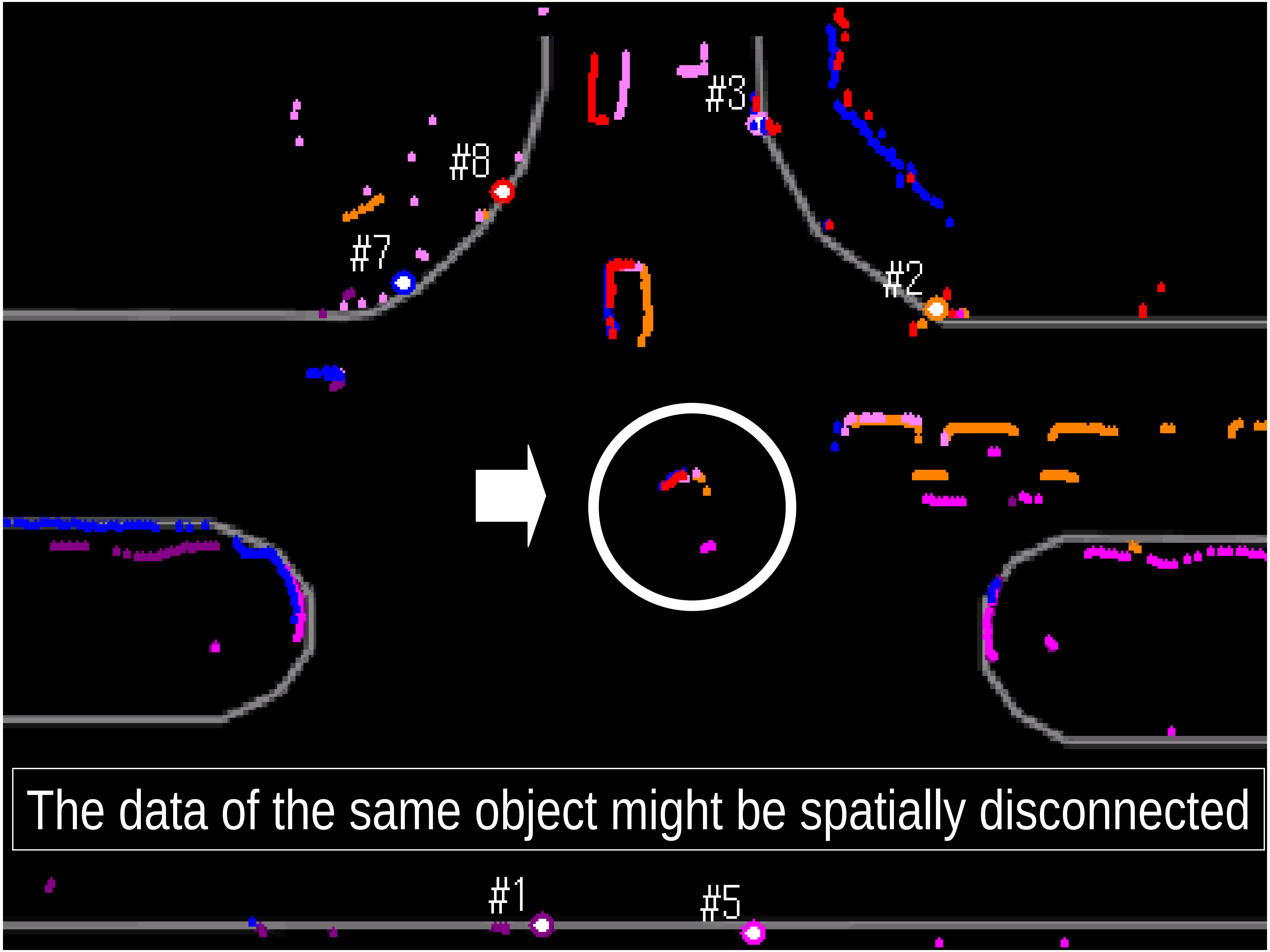
LD1
LD3
Road side
Road side
Safety zone
Safety zone
LD2
Integrated frame
LD1
Single laser frame
LD3
Single laser frame
10m
LD2
Single laser frame


#8
#3
#7
#2
#1
#5

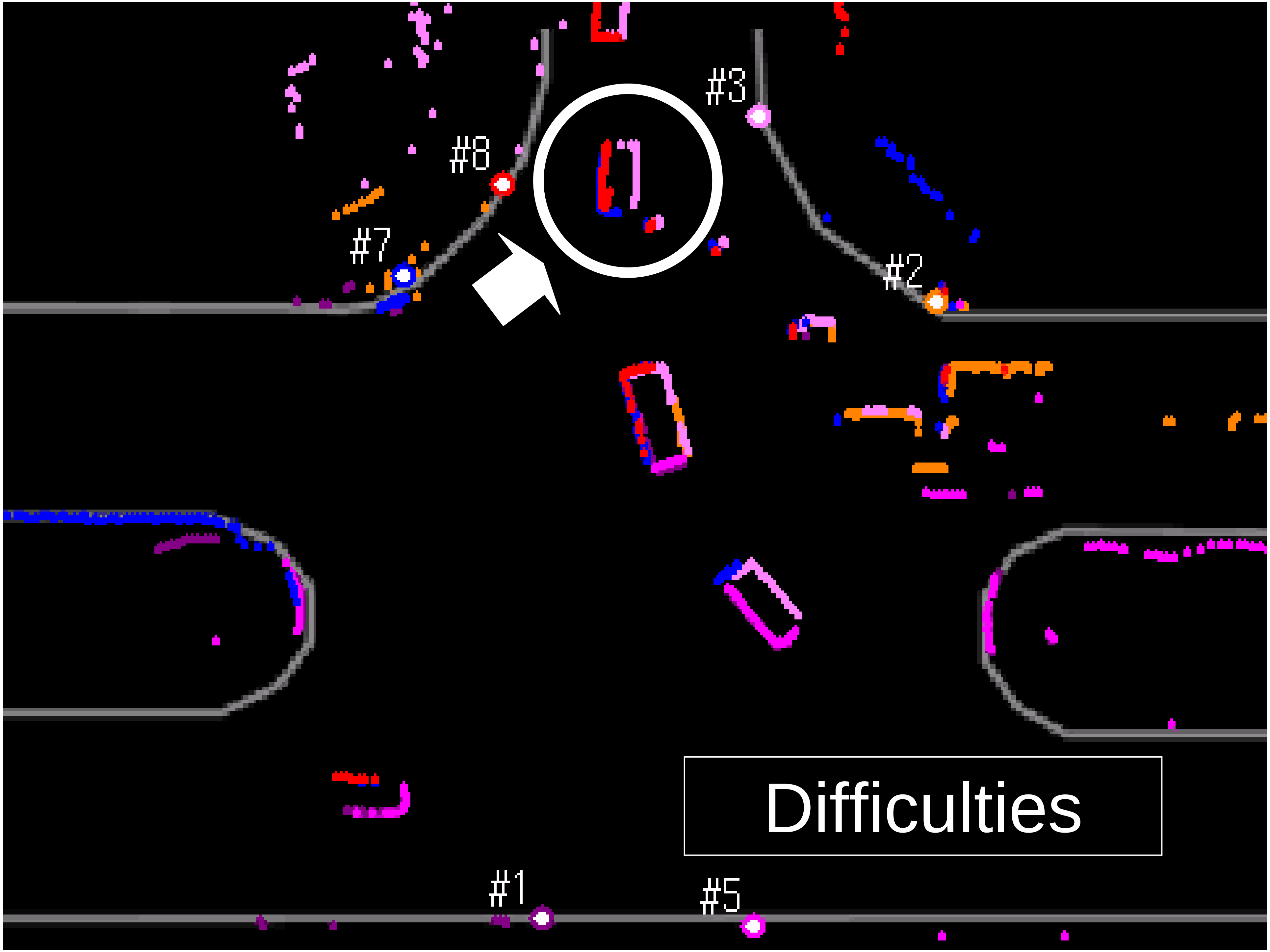
Processing Modules

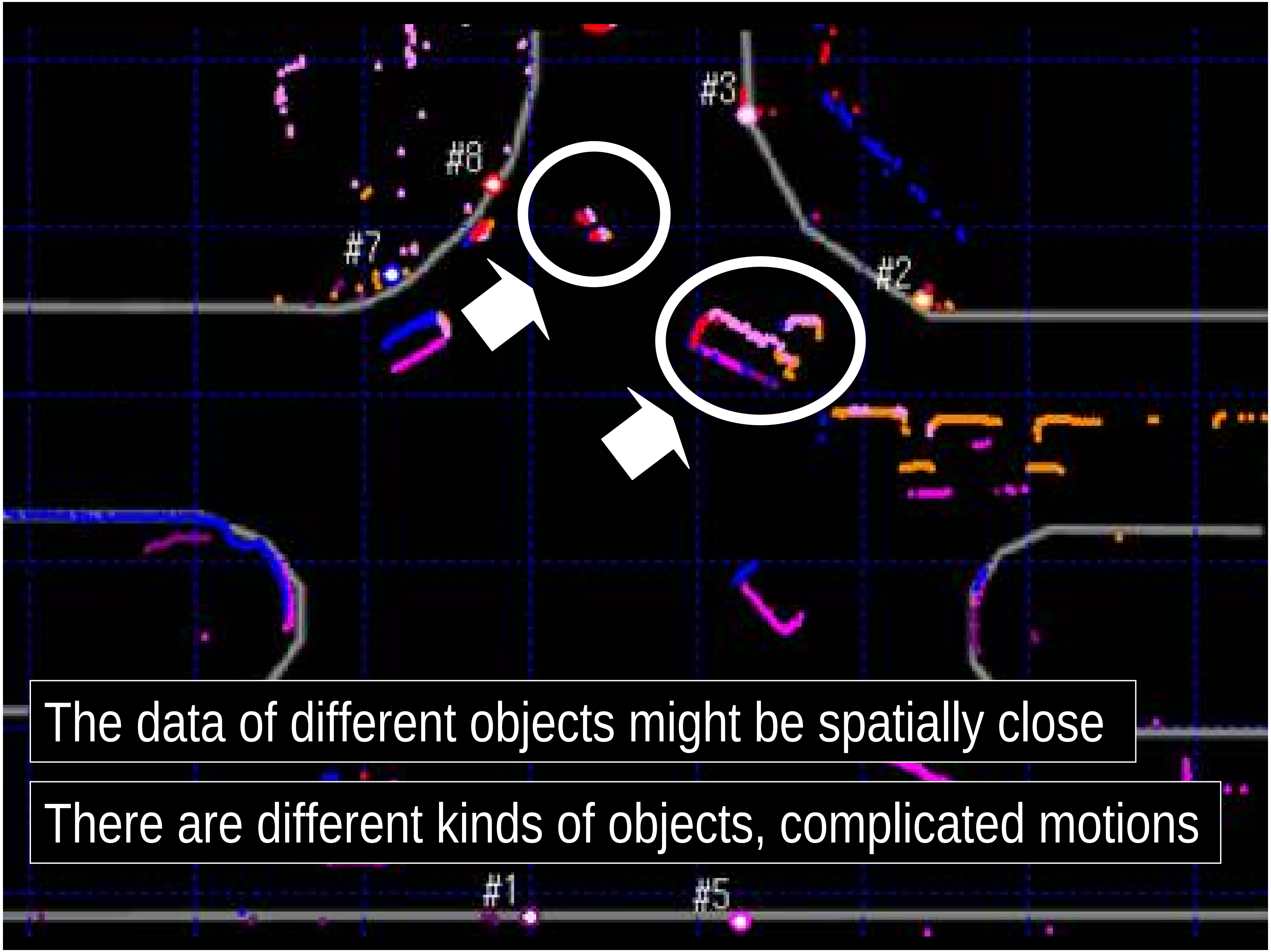



#8
#3
#7
#2
#1
#5
Difficulty 1

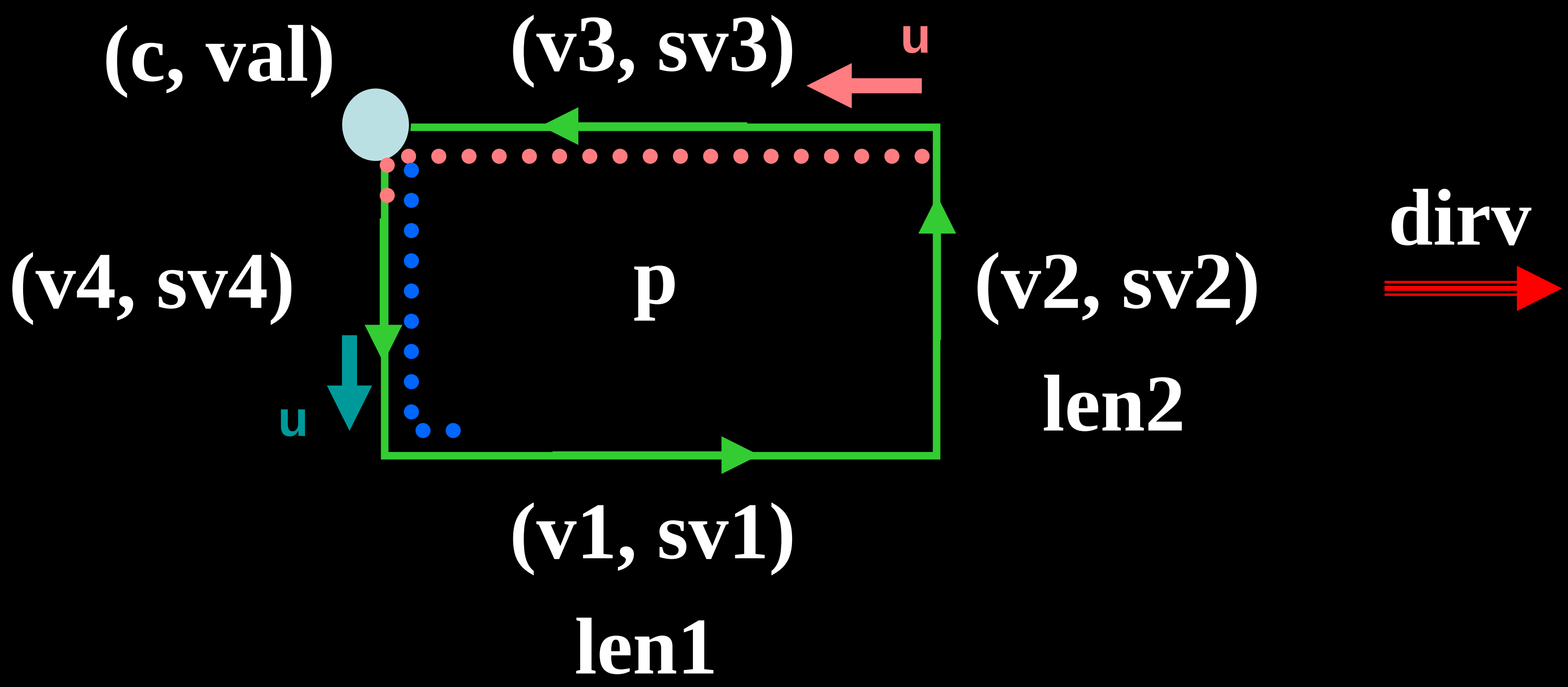


The data of the same object might be spatially disconnected


#8
#3
#7
#2
Difficulties
#1
#5


#3
#8
#7
#2
#1
#5
The data of different objects might be spatially close
There are different kinds of objects, complicated motions

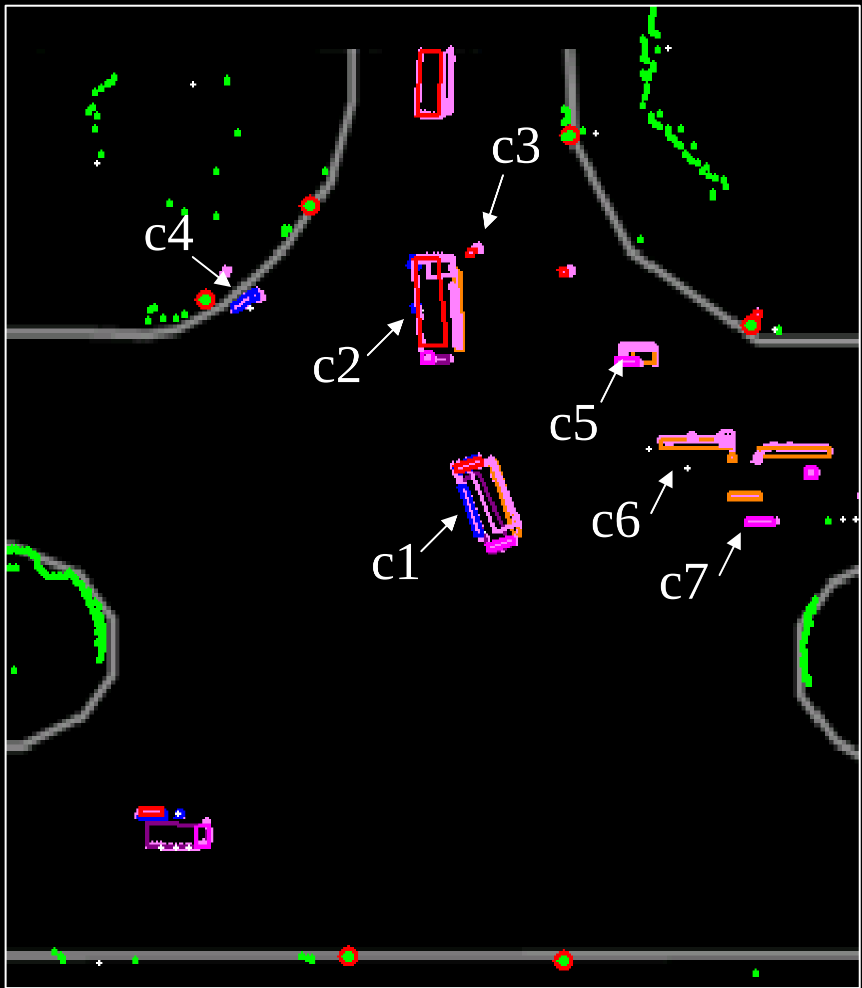
Object Model

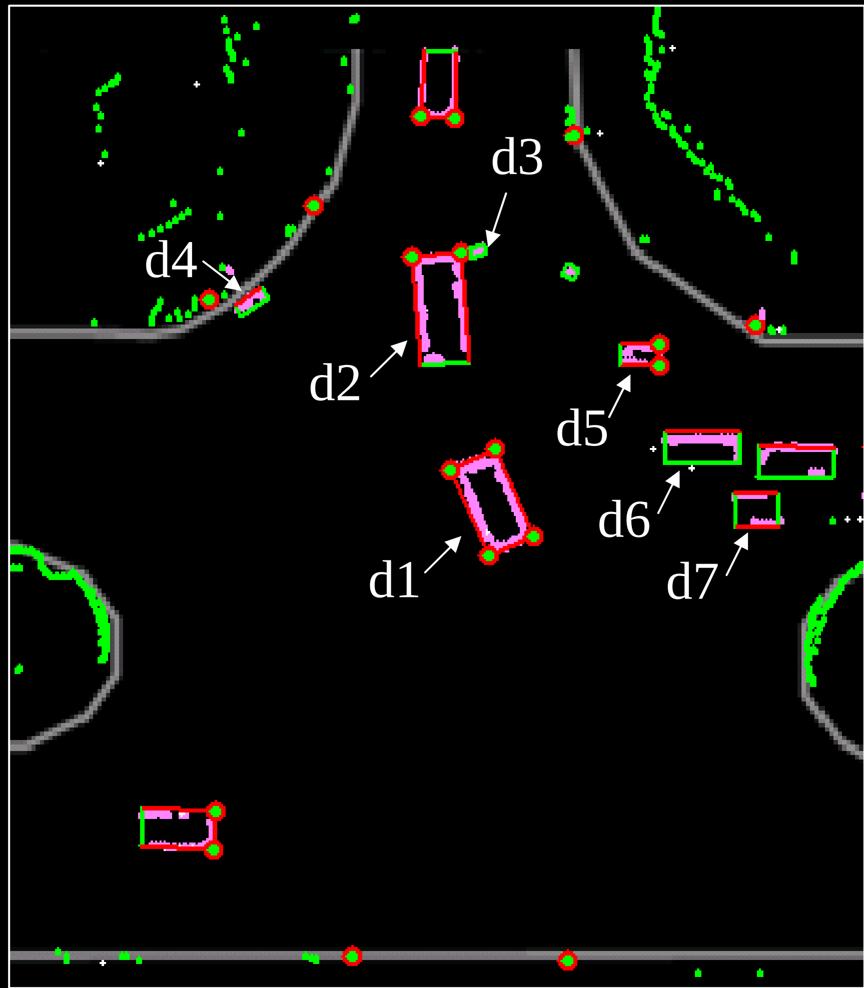


Feature parameters
and their reliabilities

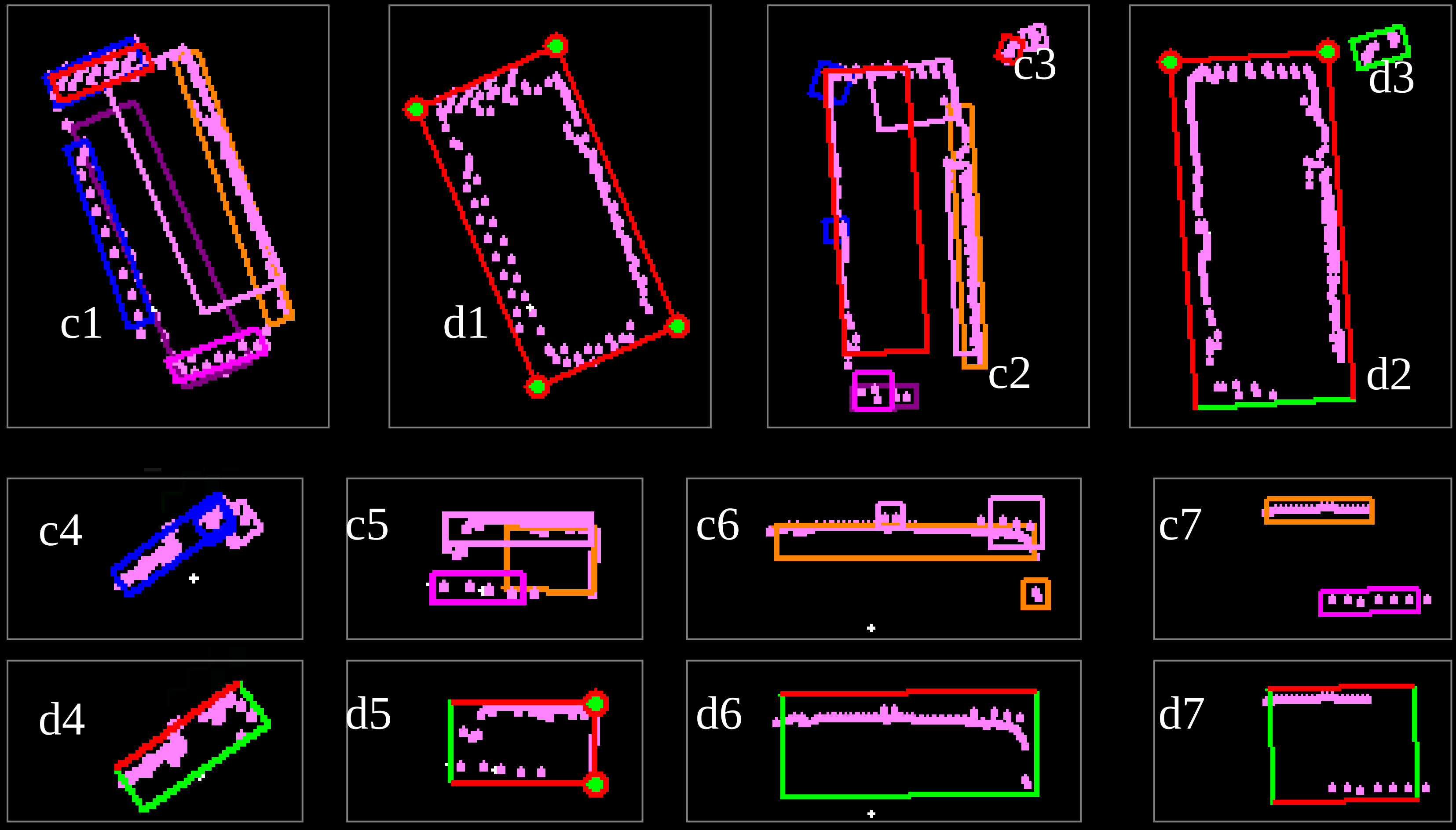
(v1=dirv)

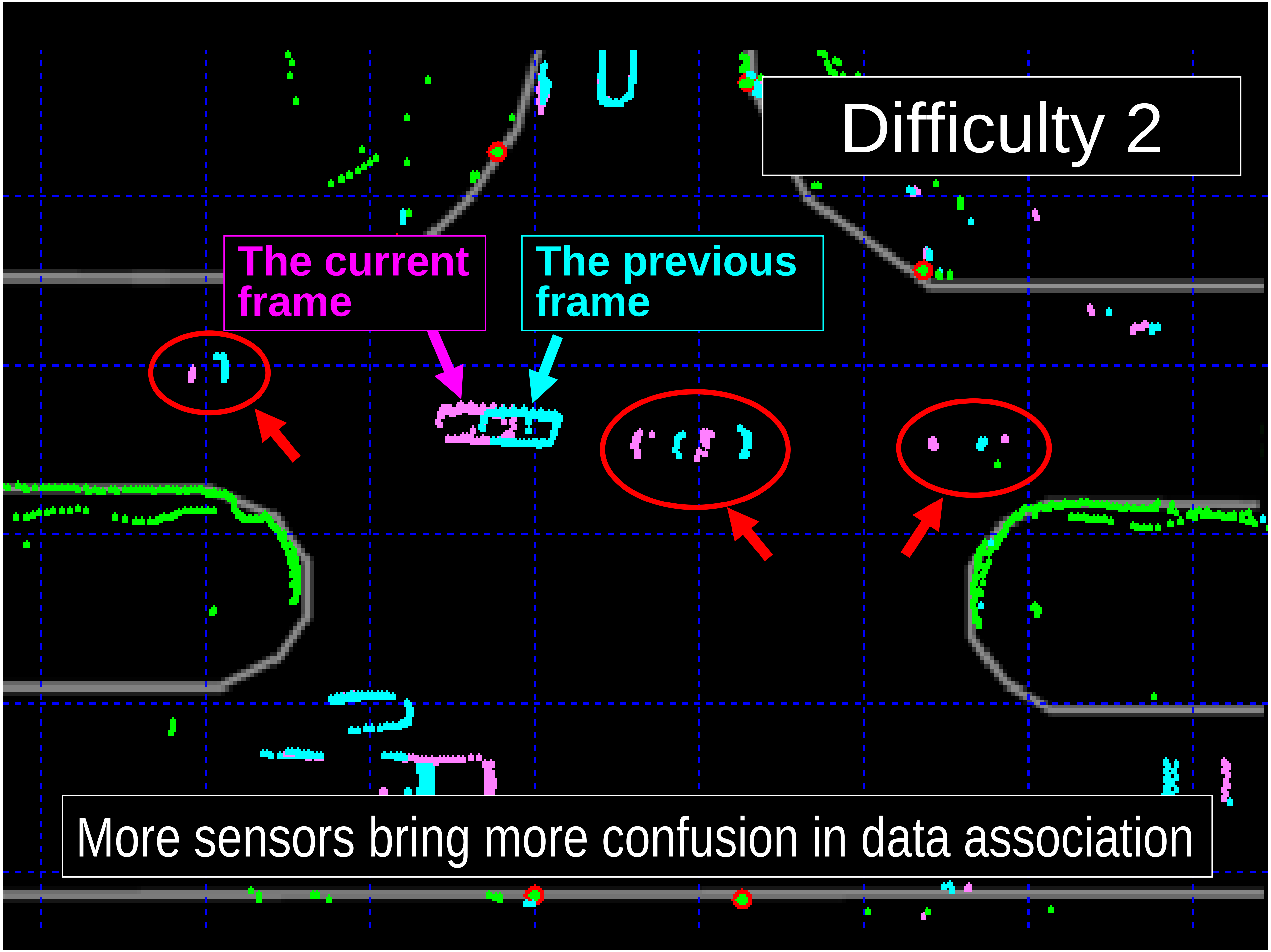
Object Detection Results

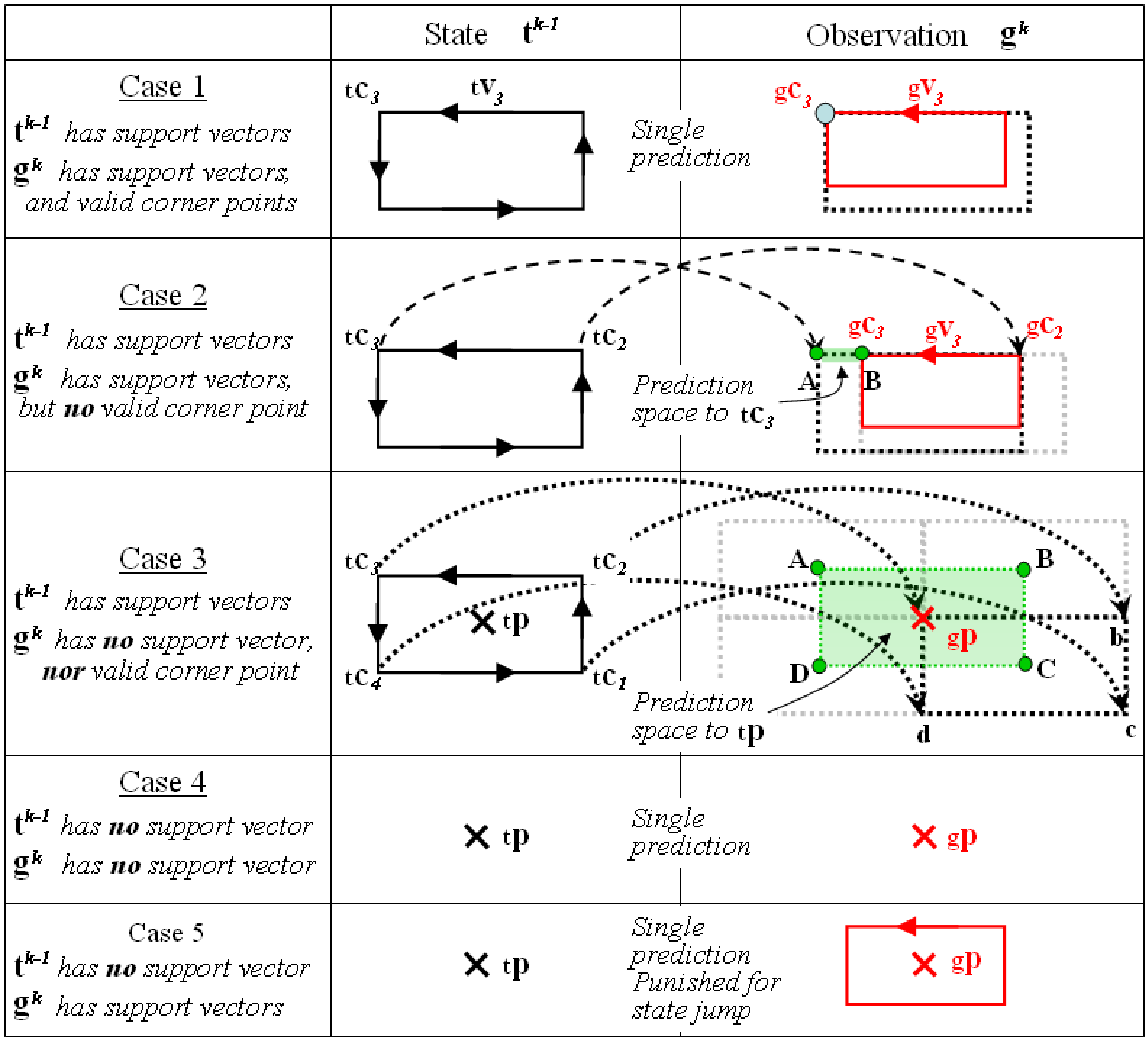




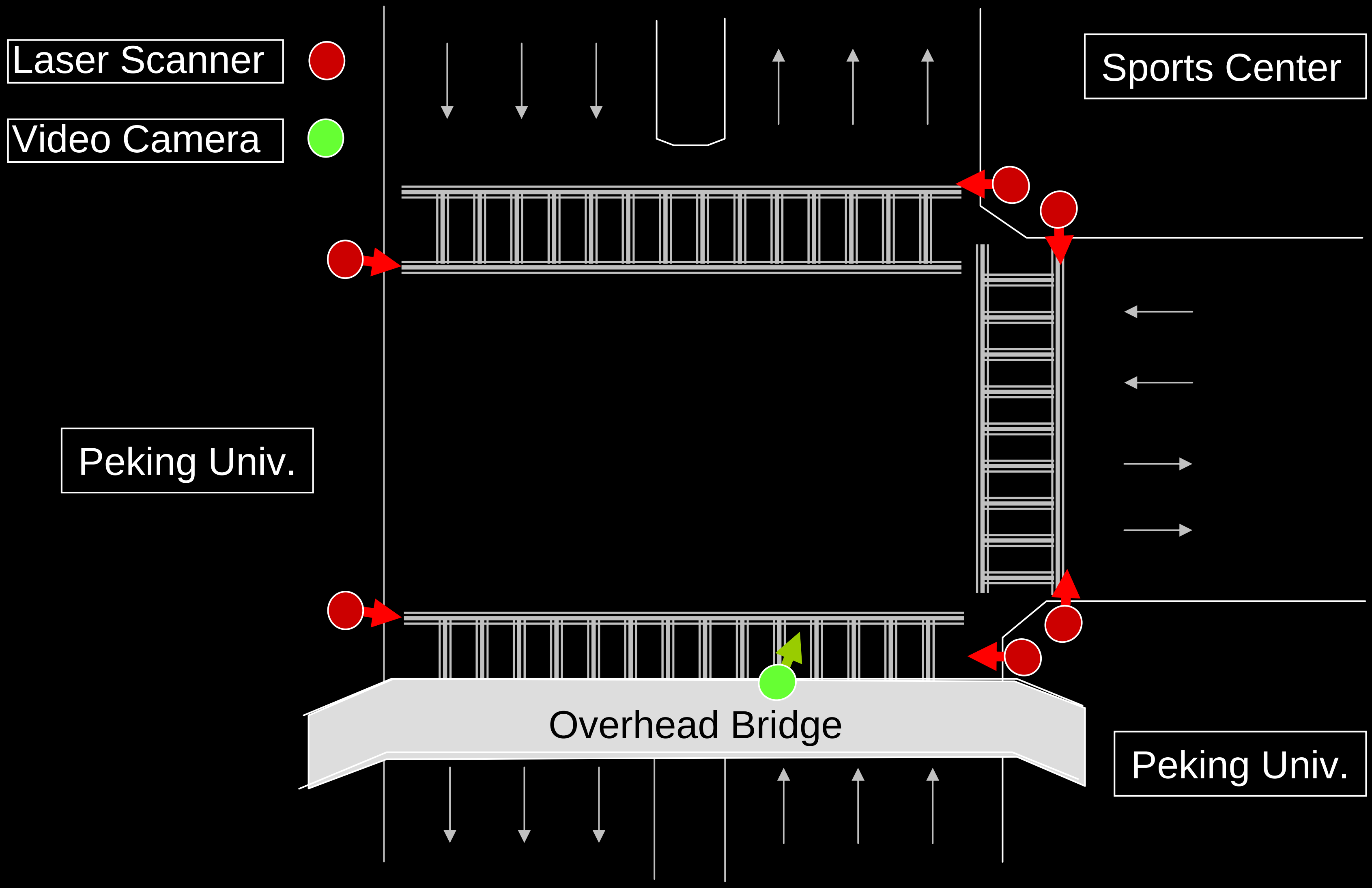
Object Detection Results



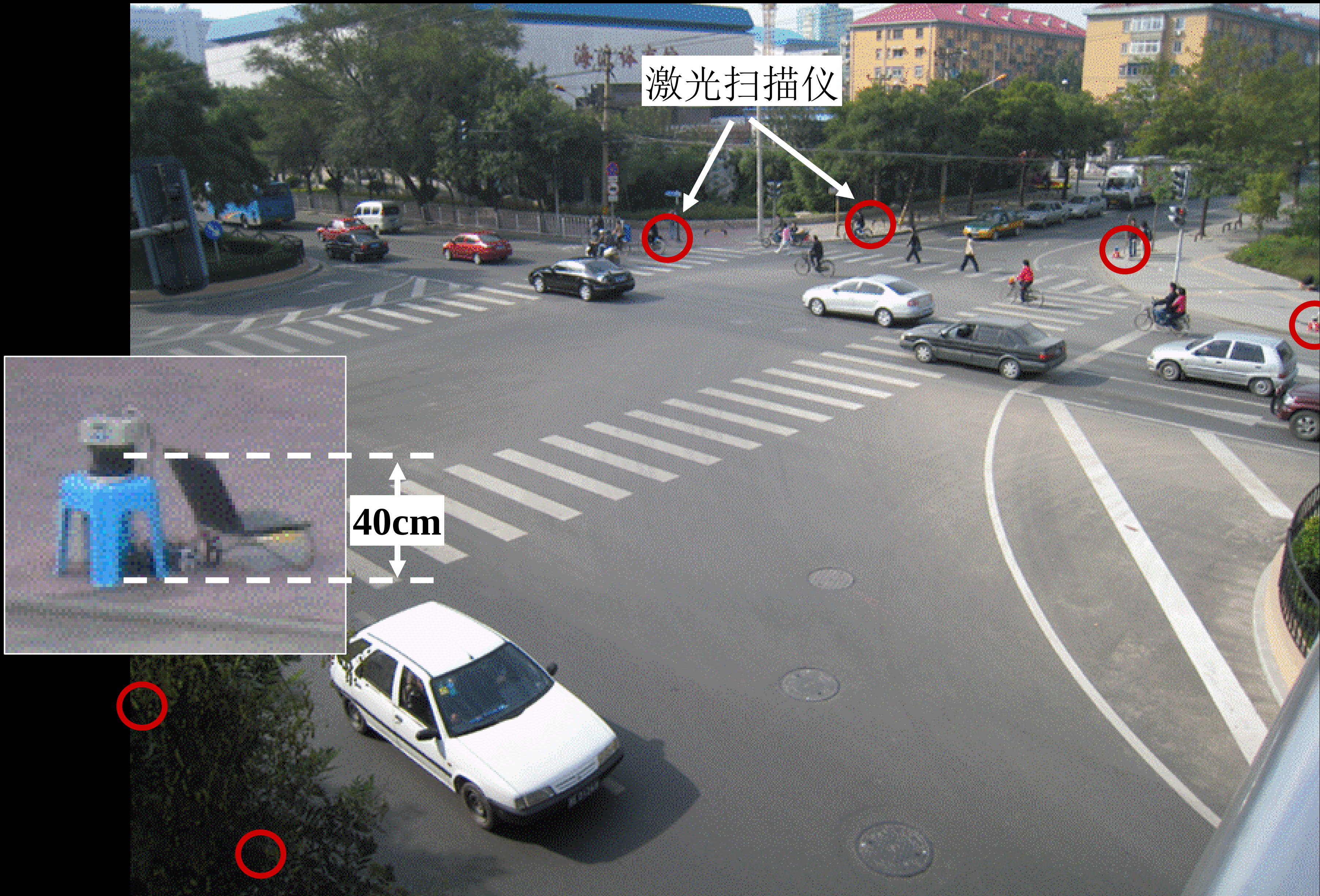

Difficulty 2
The current frame
The previous frame
More sensors bring more confusion in data association


State t^{k-1}
Observation g^k
Case 1
t^{k-1} has support vectors
g^k has support vectors, and valid corner points
tC_3
tV_3
Single prediction
gC_3
gV_3
Case 2
t^{k-1} has support vectors
g^k has support vectors, but **no** valid corner point
tC_3
tC_2
Prediction space to tC_3
gC_3
gV_3
gC_2
A
B
Case 3
t^{k-1} has support vectors
g^k has **no** support vector, **nor** valid corner point
tC_3
tC_2
tC_4
tC_1
tp
Prediction space to tp
A
B
C
D
gp
b
c
d
Case 4
t^{k-1} has **no** support vector
g^k has **no** support vector
tp
Single prediction
gp
Case 5
t^{k-1} has **no** support vector
g^k has support vectors
tp
Single prediction Punished for state jump
gp

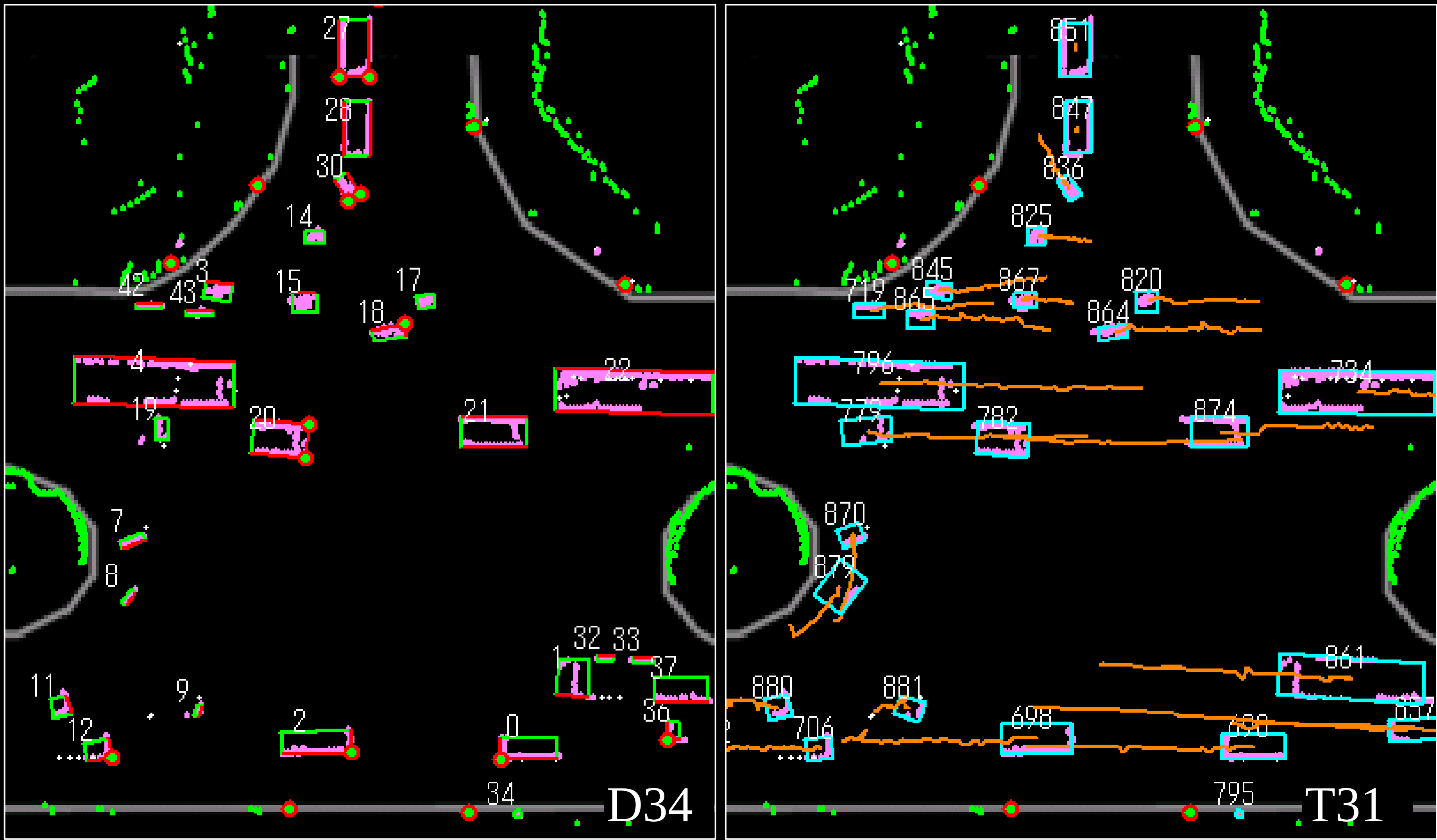
Experiment



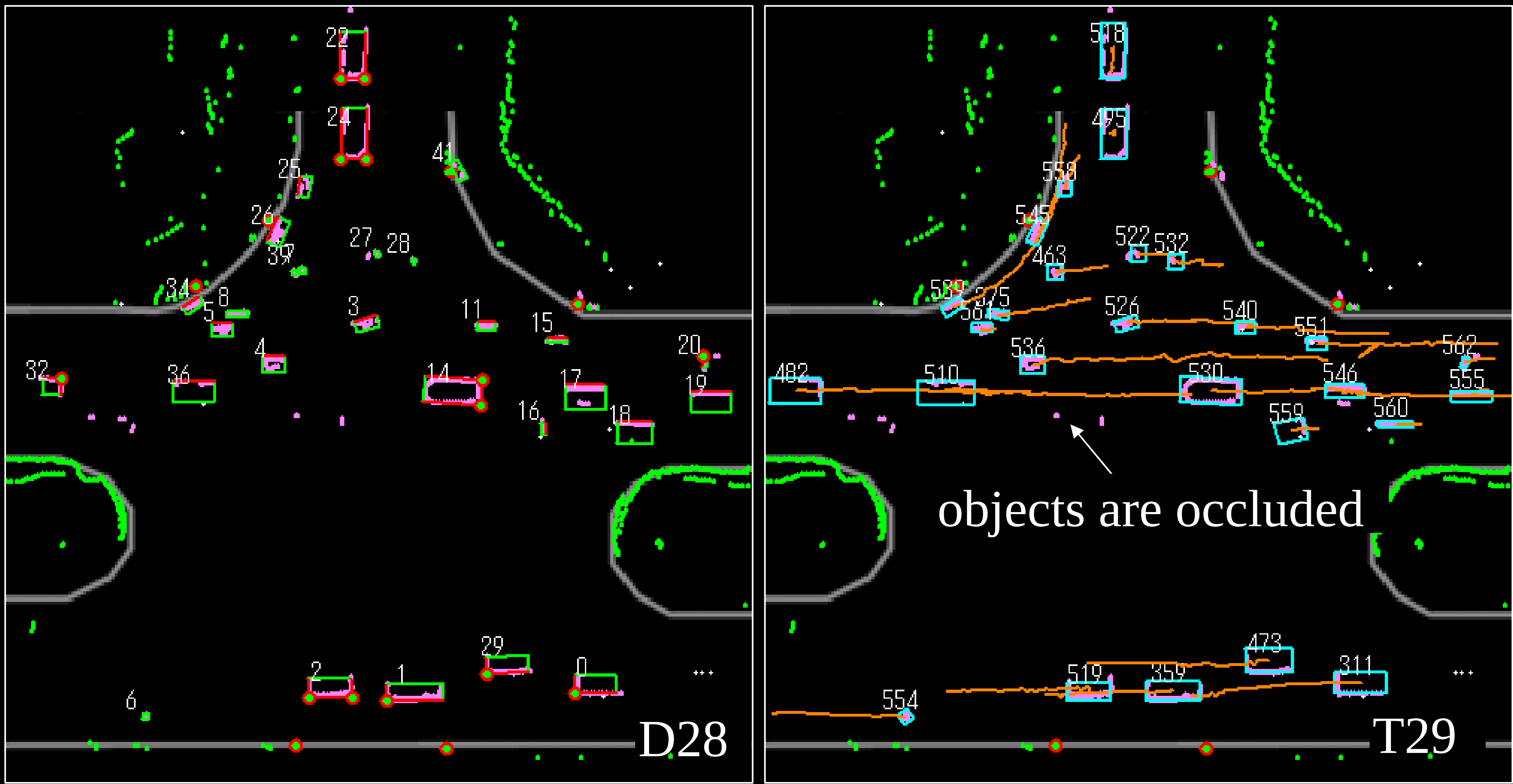
Laser Scanner
Video Camera
Sports Center
Peking Univ.
Overhead Bridge
Peking Univ.


激光扫描仪
40cm

Results



Results



Accuracy Analysis

2007.10.13, 10:00-10:20

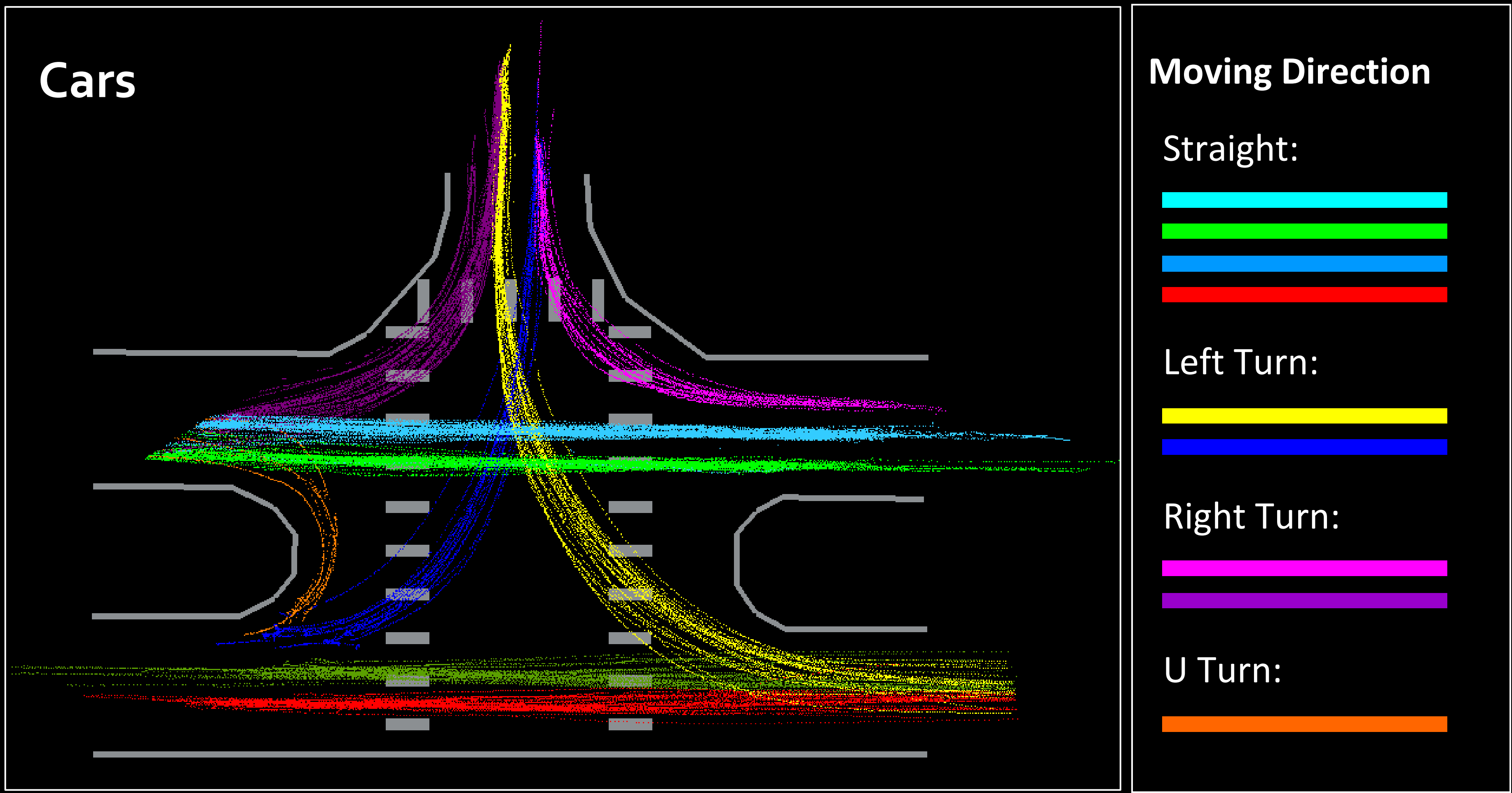
Detection Results

type	perfect	split	merge	none	total	d.ratio	p.ratio
car	6915	614	7	89	7625	0.988	0.907
bicycle	1571	82	0	24	1677	0.986	0.938
pedes.	799	13	508	130	1450	0.910	0.551
sum.	9285	709	515	243	10752	0.977	0.864

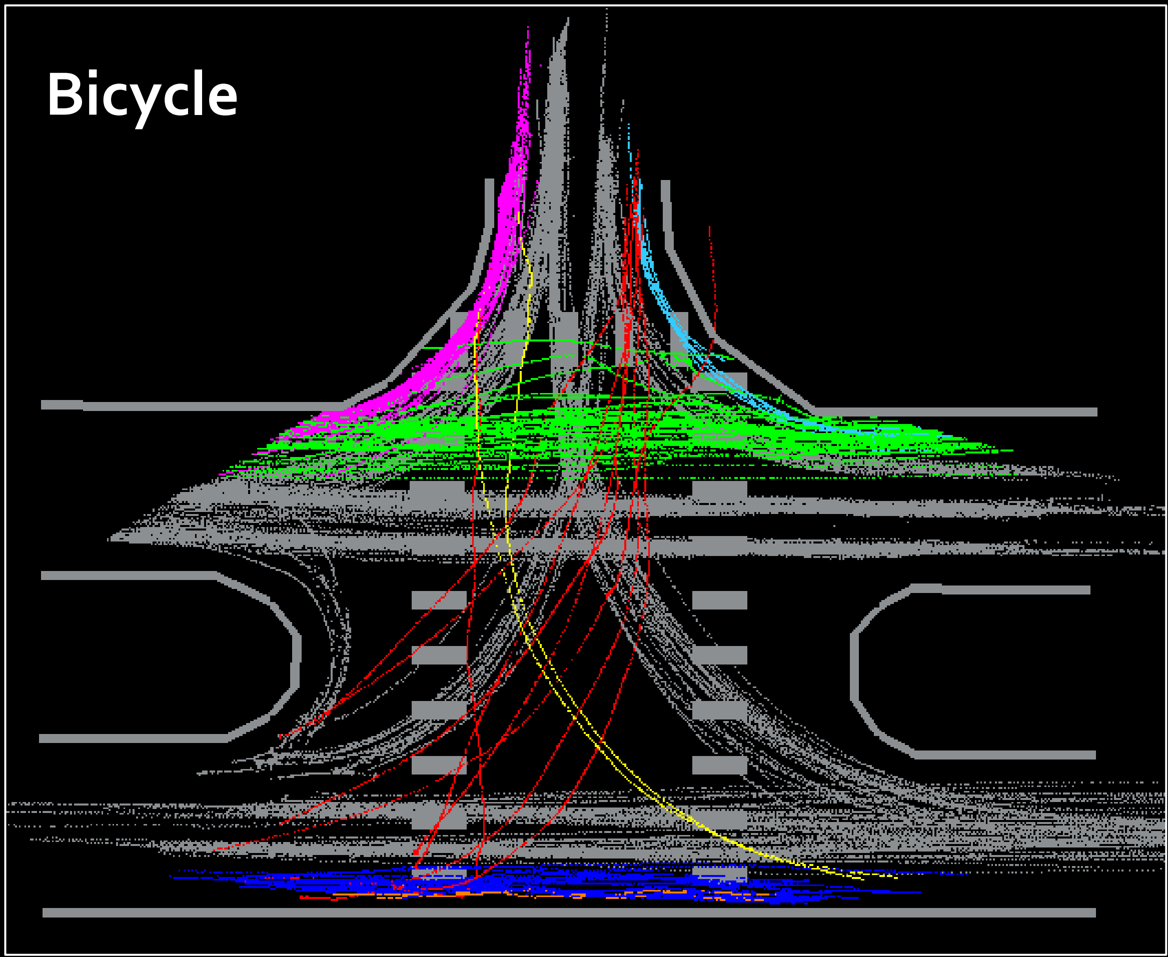
Tracking Results

type	perfect	broken	error	total	t.ratio	p.ratio
car	636	22	17	675	0.975	0.942
bicycle	322	8	21	351	0.940	0.917
pedes.	30	2	5	37	0.865	0.811
sum.	988	32	43	1063	0.960	0.929

Trajectory Clustering



Trajectory Clustering



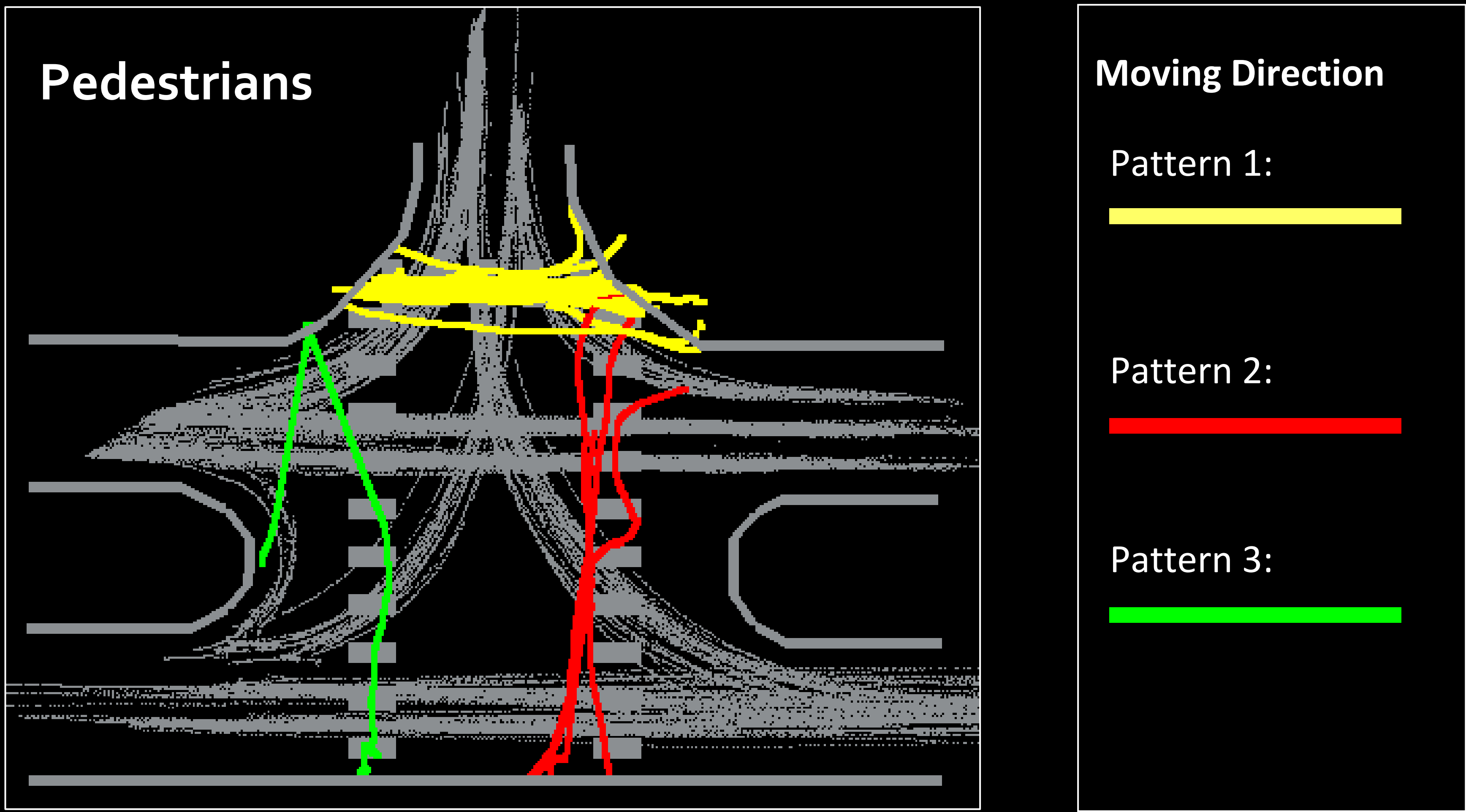
Moving Direction

Straight:

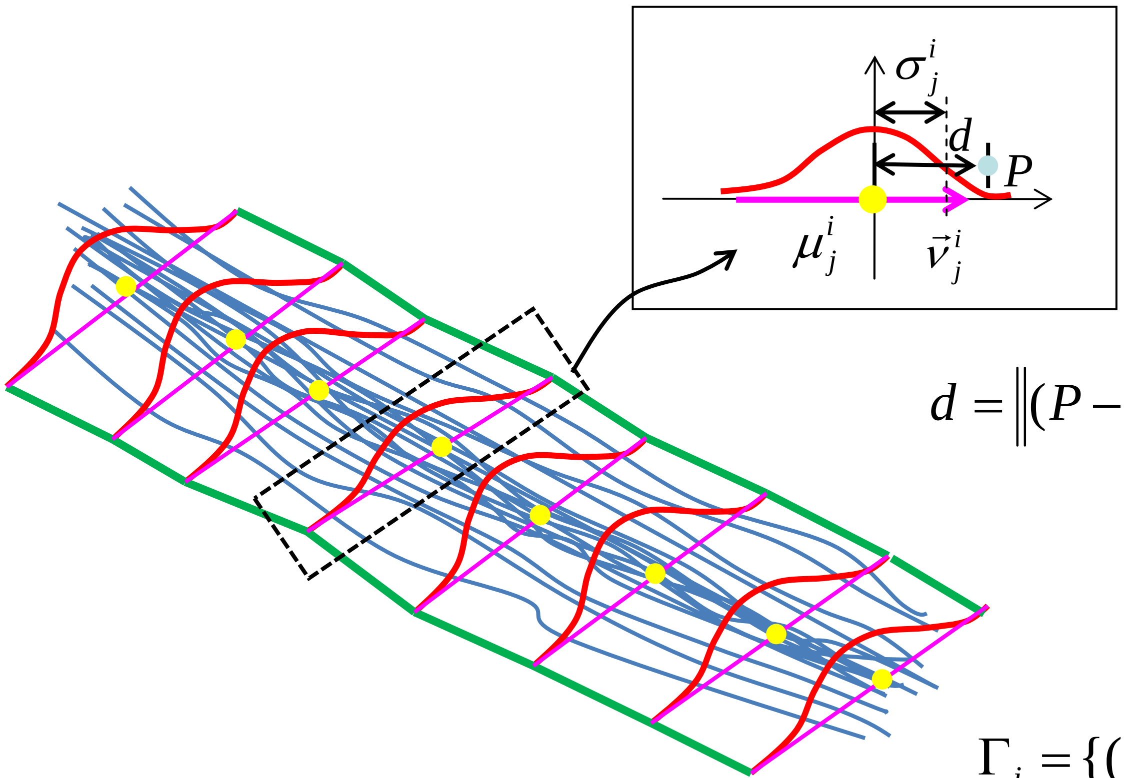
Crossing:

Turn along road:

Trajectory Clustering



Path Model



$$d = \left\| (P - \mu_j^i) \cdot \vec{v}_j^i \right\| \sim N(0, \sigma_j^i)$$

$$\Gamma_j = \{ (\mu_j^i, \vec{v}_j^i, \sigma_j^i) \mid i = 1, 2, \ldots, n_j \}$$

Each cross-section is represented by a Gaussian
A path is model as a sequence of Gausians

Trajectory Evaluation

Likelihood between a trajectory T_k and a path Γ_j is evaluated

$$P(T_k \mid \Gamma_j) \propto \prod_{p=1}^{L_k} P(T_k^p \mid \Gamma_j) \quad // \ T_k^p \text{ is a trajectory point}$$

$$= \prod_{p=1}^{L_k} P(T_k^p \mid \Gamma_j^{i'}) \quad // \ \Gamma_j^{i'} \text{ is the nearest cross-section to } T_k^p$$

$$P(T_k^p \mid \Gamma_j^{i'}) = \frac{1}{\sqrt{2\pi}\sigma_j^{i'}} e^{-d^2 / 2\sigma_j^{i'2}}$$

Trajectory Classification

Given a trajectory T_* , the objective is to classify it with in

$$class = \{\Gamma_1, \Gamma_2, \ldots, \Gamma_n, \boxed{\Gamma_a}\}$$

as

$$\Gamma_* = \max_{\Gamma} \arg P(\Gamma \mid T_*)$$

where

$$P(\Gamma_i \mid T_*) = \frac{1}{\eta} P(T_* \mid \Gamma_i) P(\Gamma_i)$$

$$P(\Gamma_a \mid T_*) = \frac{1}{\eta} P(T_* \mid \Gamma_a) P(\Gamma_a)$$

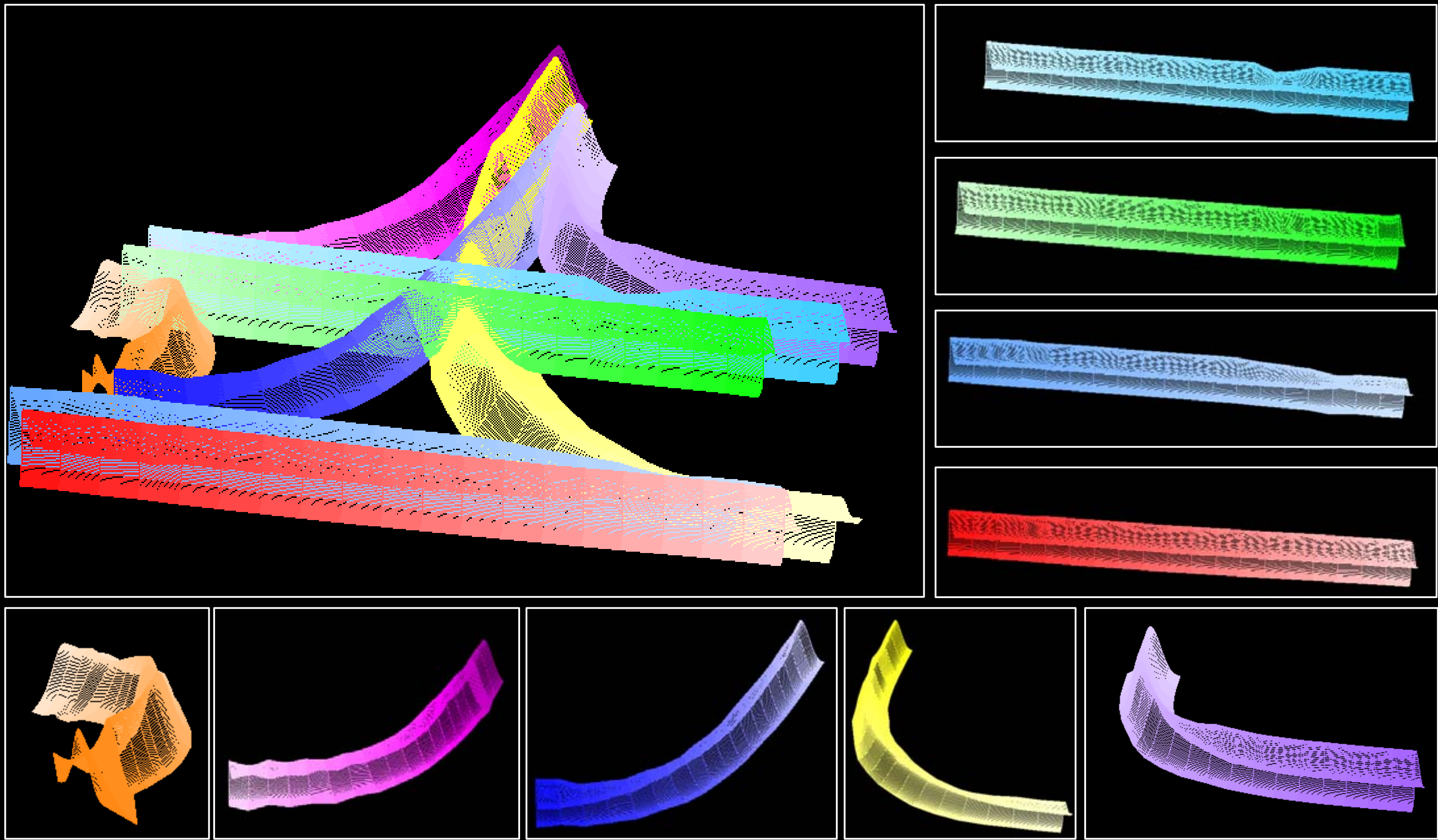
and

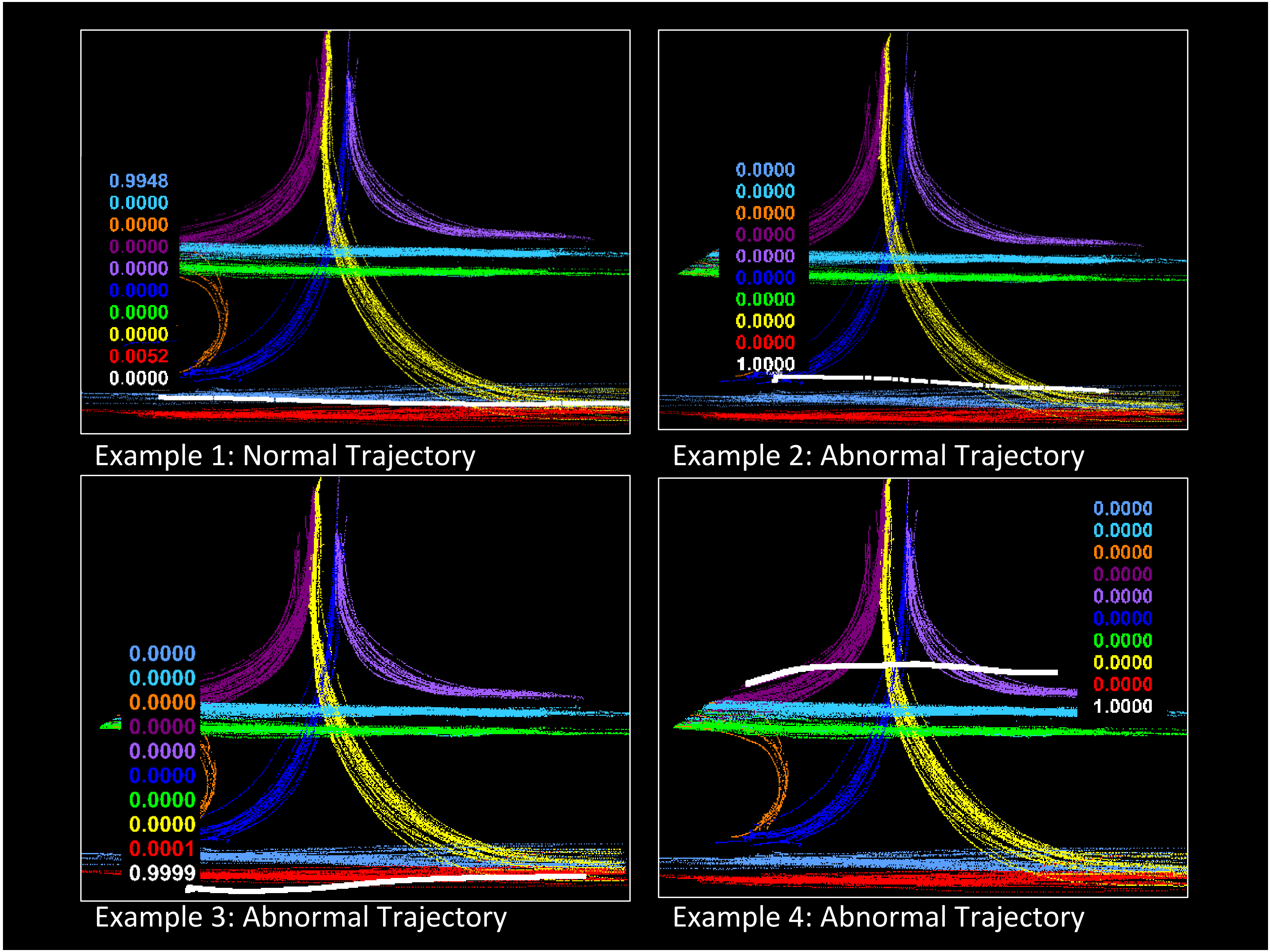
$$P(T_* \mid \Gamma_a) = \prod_{i=1}^{n} (P(T_* \mid \Gamma_i) < \varepsilon_i), \in \{0,1\}$$

$P(T_* \mid \Gamma_a)$ can be either 0 or 1.

$P(T_* \mid \Gamma_a) = 1$ if and only if $\forall i \quad P(T_* \mid \Gamma_i) < \varepsilon_i$

Path models





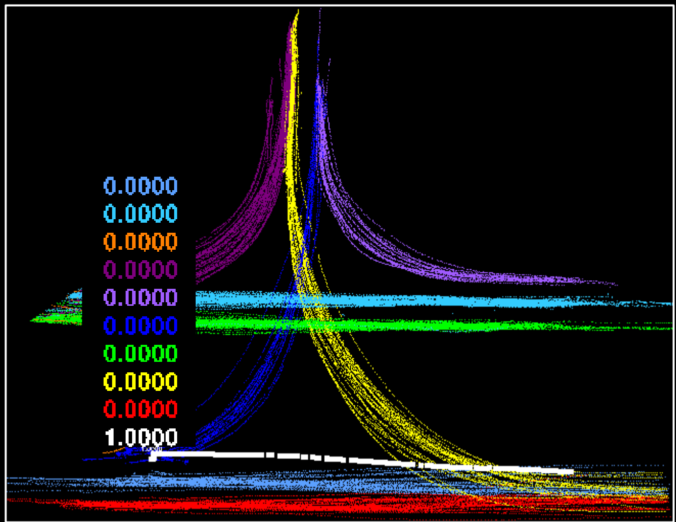
Example 1: Normal Trajectory

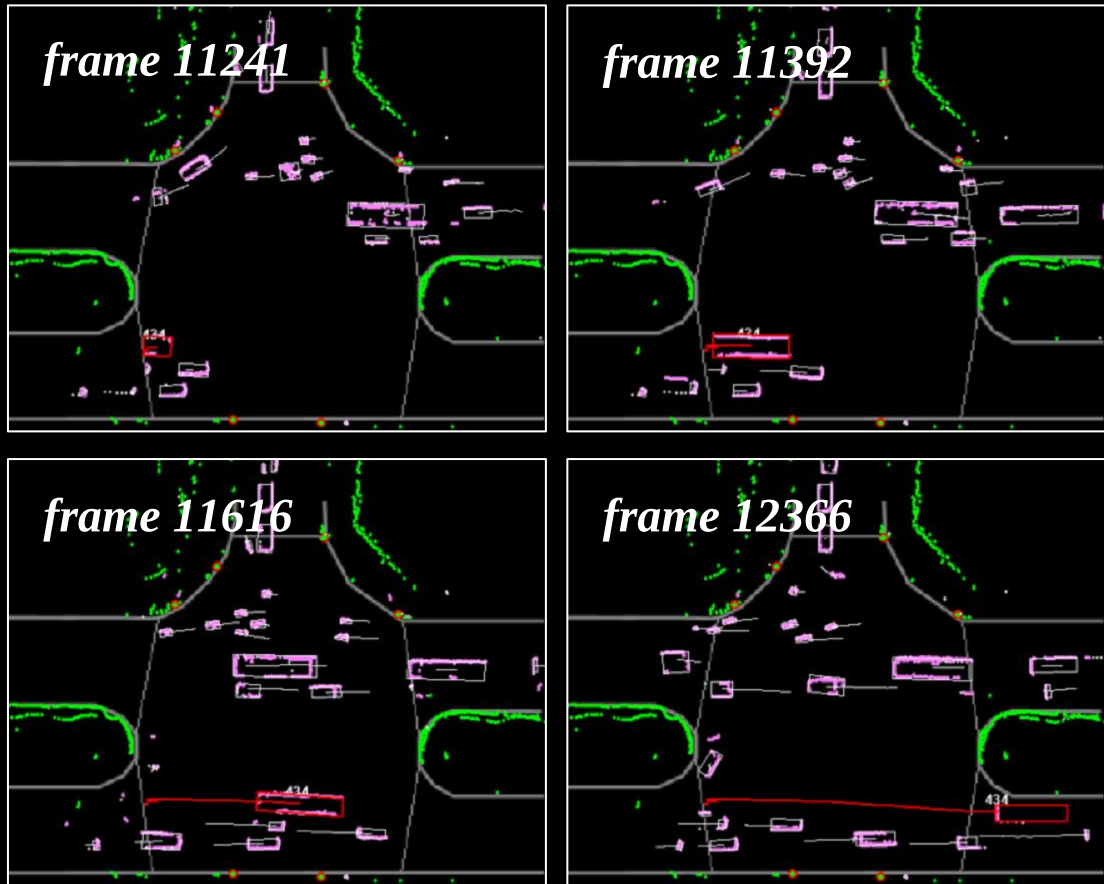
Example 2: Abnormal Trajectory

Example 3: Abnormal Trajectory

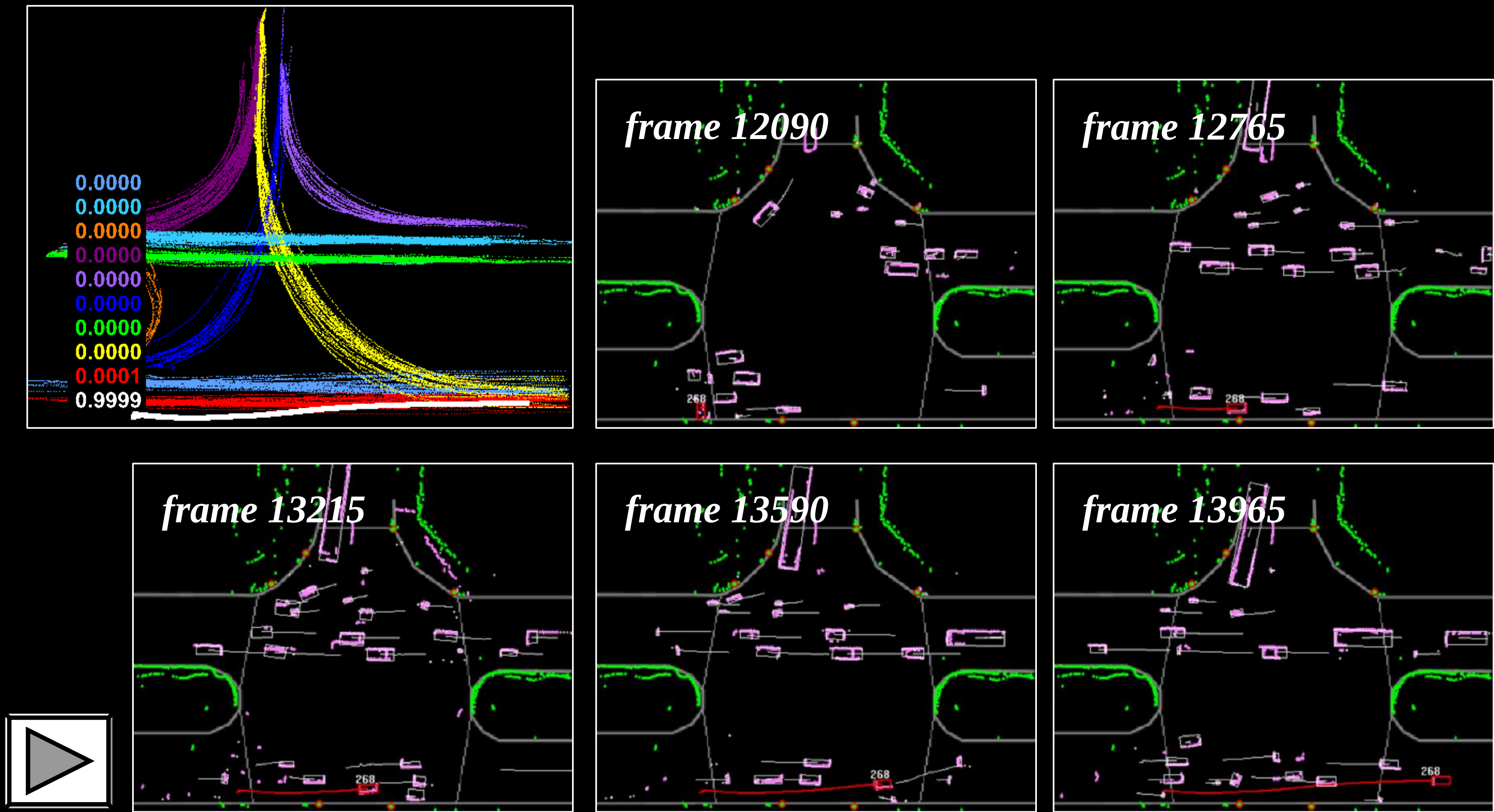
Example 4: Abnormal Trajectory

Real Abnormal Trajectory

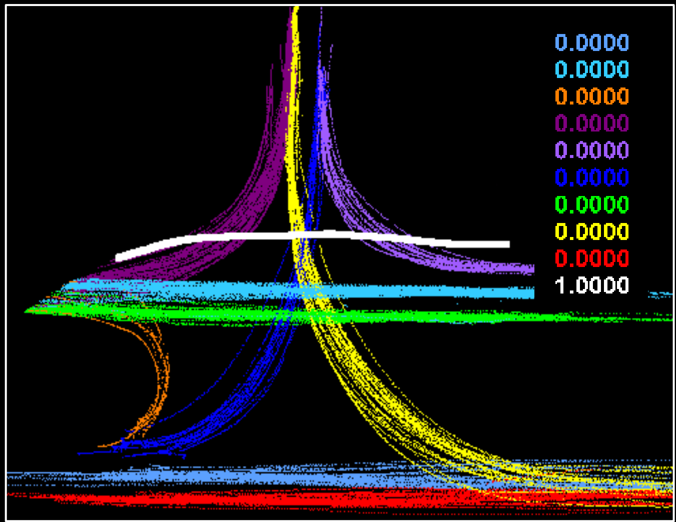


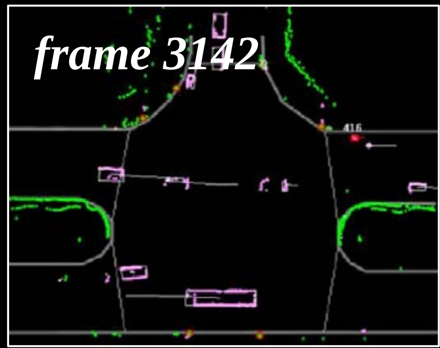


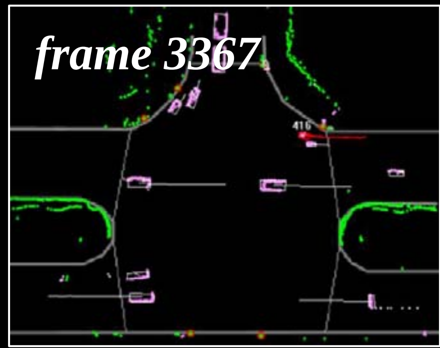
Real Abnormal Trajectory

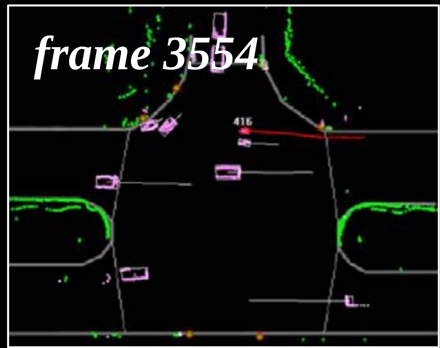


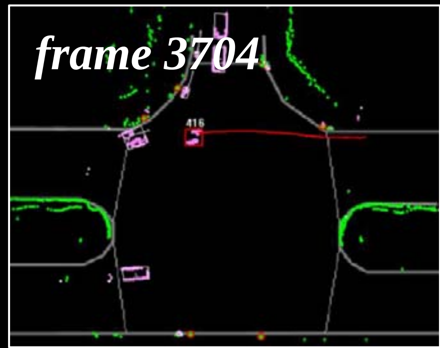
False Abnormal Trajectory

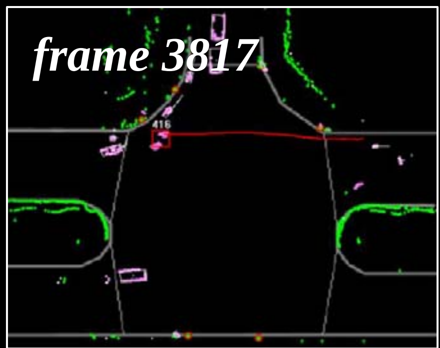


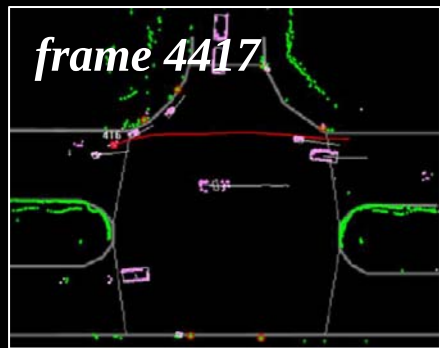












Thank You!

Contact Info:

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http://www.cis.pku.edu.cn/faculty/vision/zhaohj/