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

To solve the problems

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

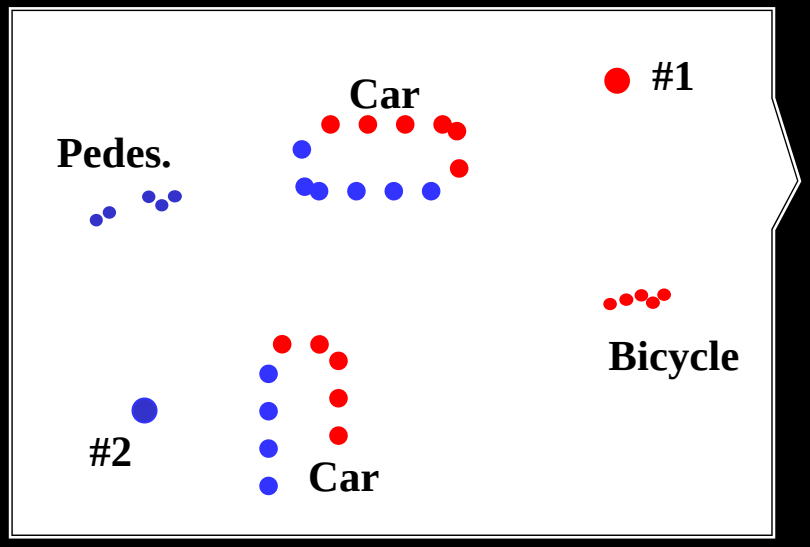
e.g. the camera is required to be set on a tall position, monitoring intersection from the above

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

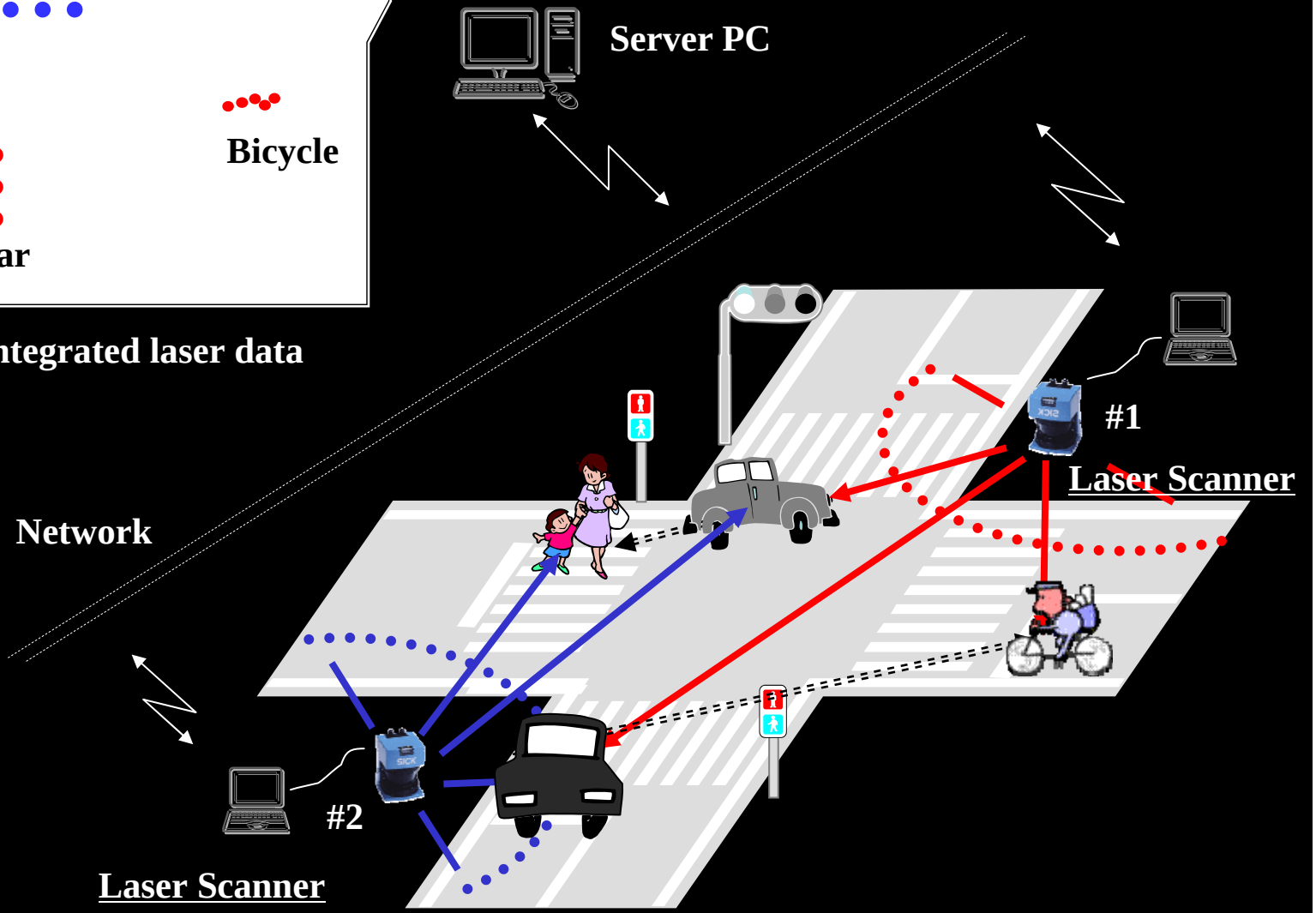
Objective

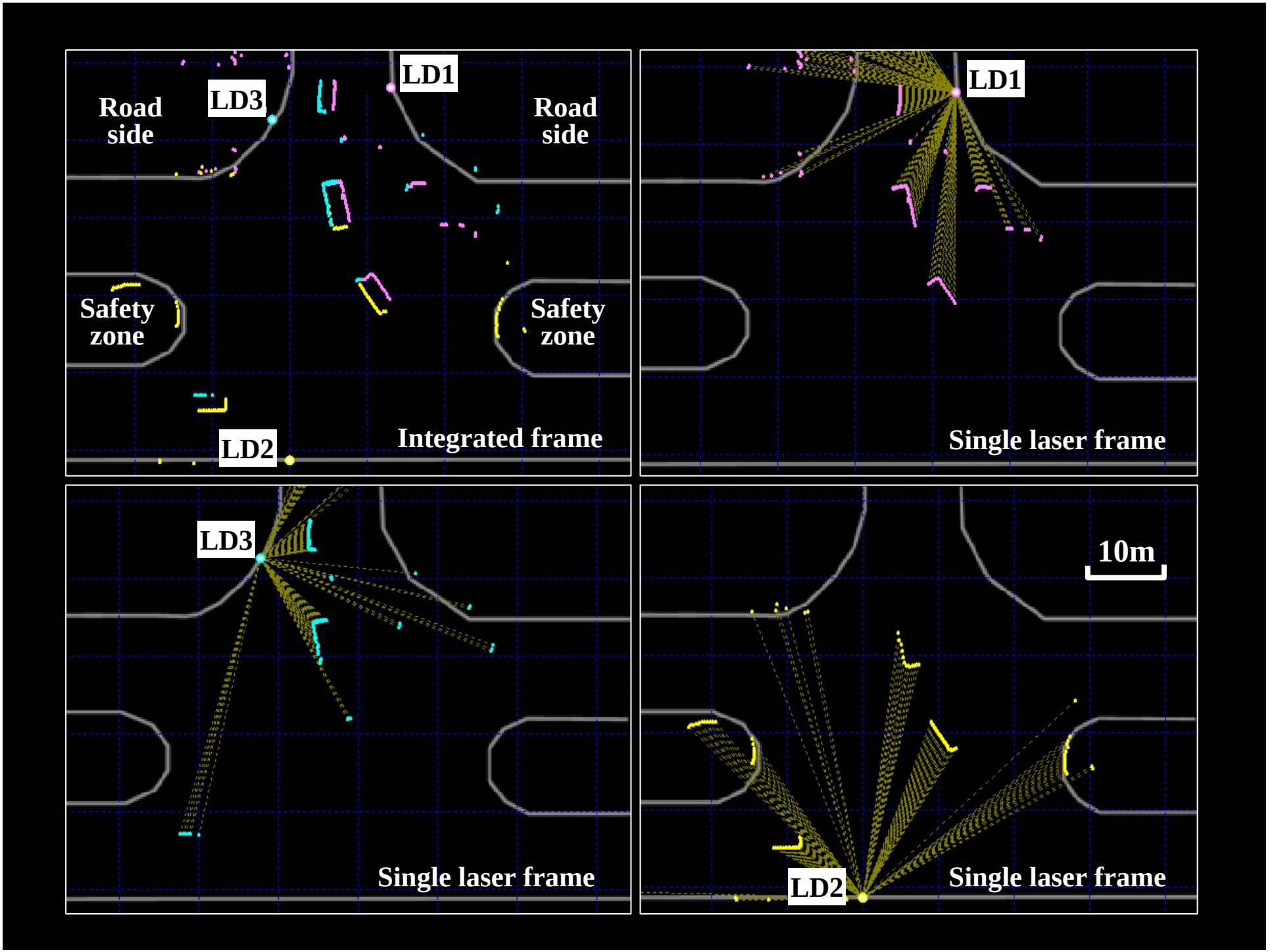
This research propose a novel system for monitoring and collecting **detailed traffic data**, with **easy setting condition**, in an environment of complicated traffic behavior, such as **intersection**, using **a network of single-row laser scanner.**

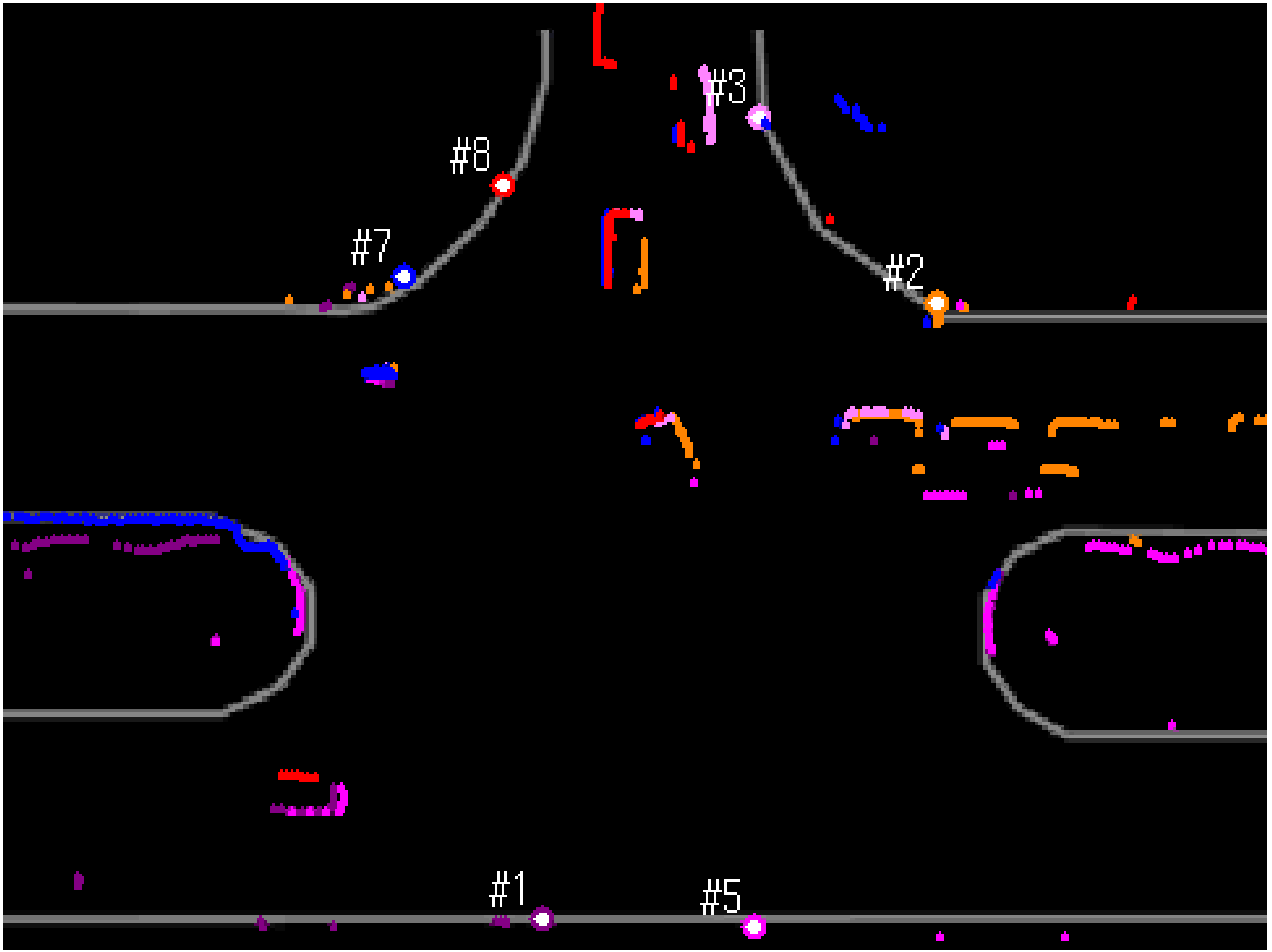
System Image

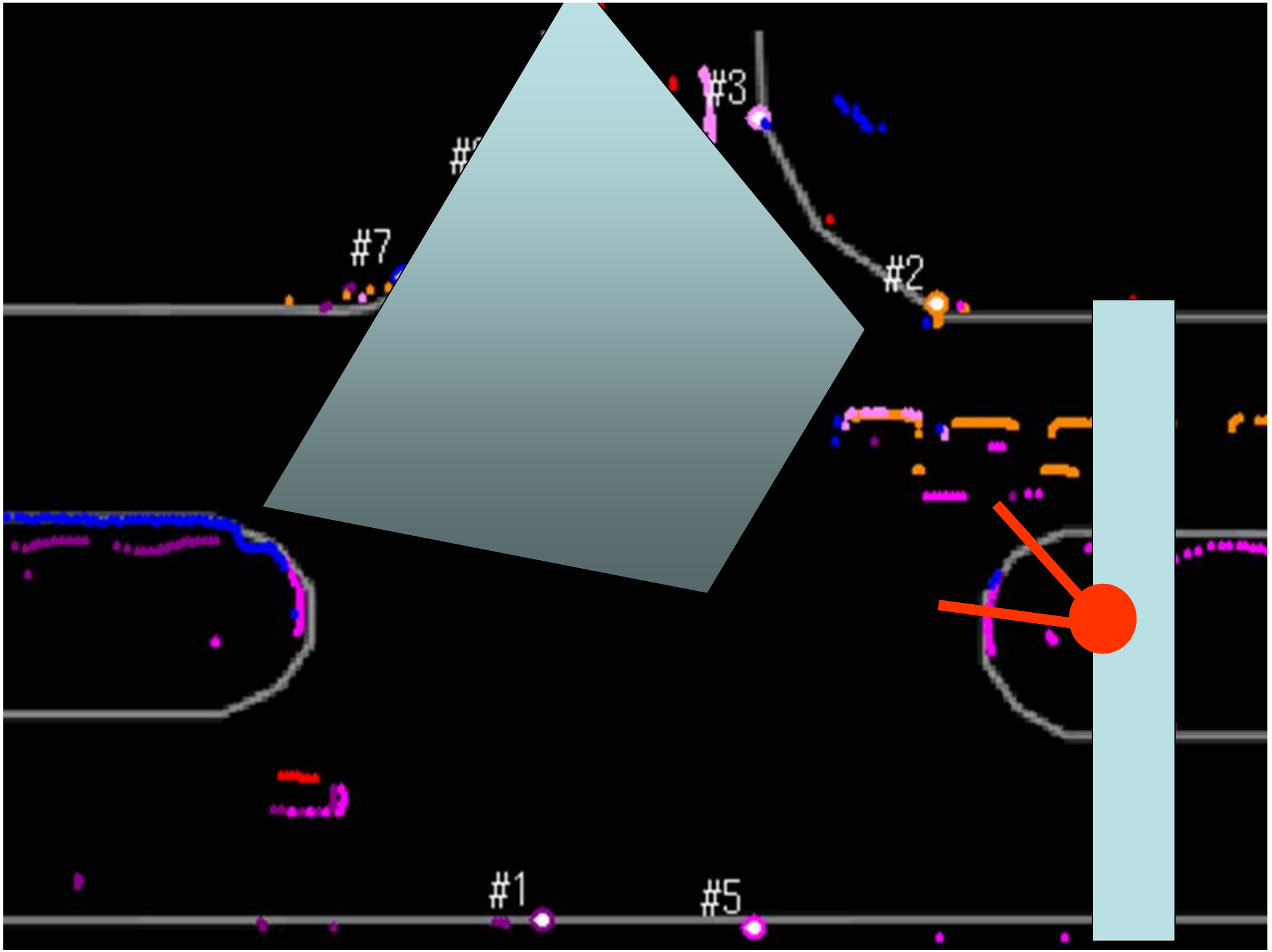


An image of integrated laser data

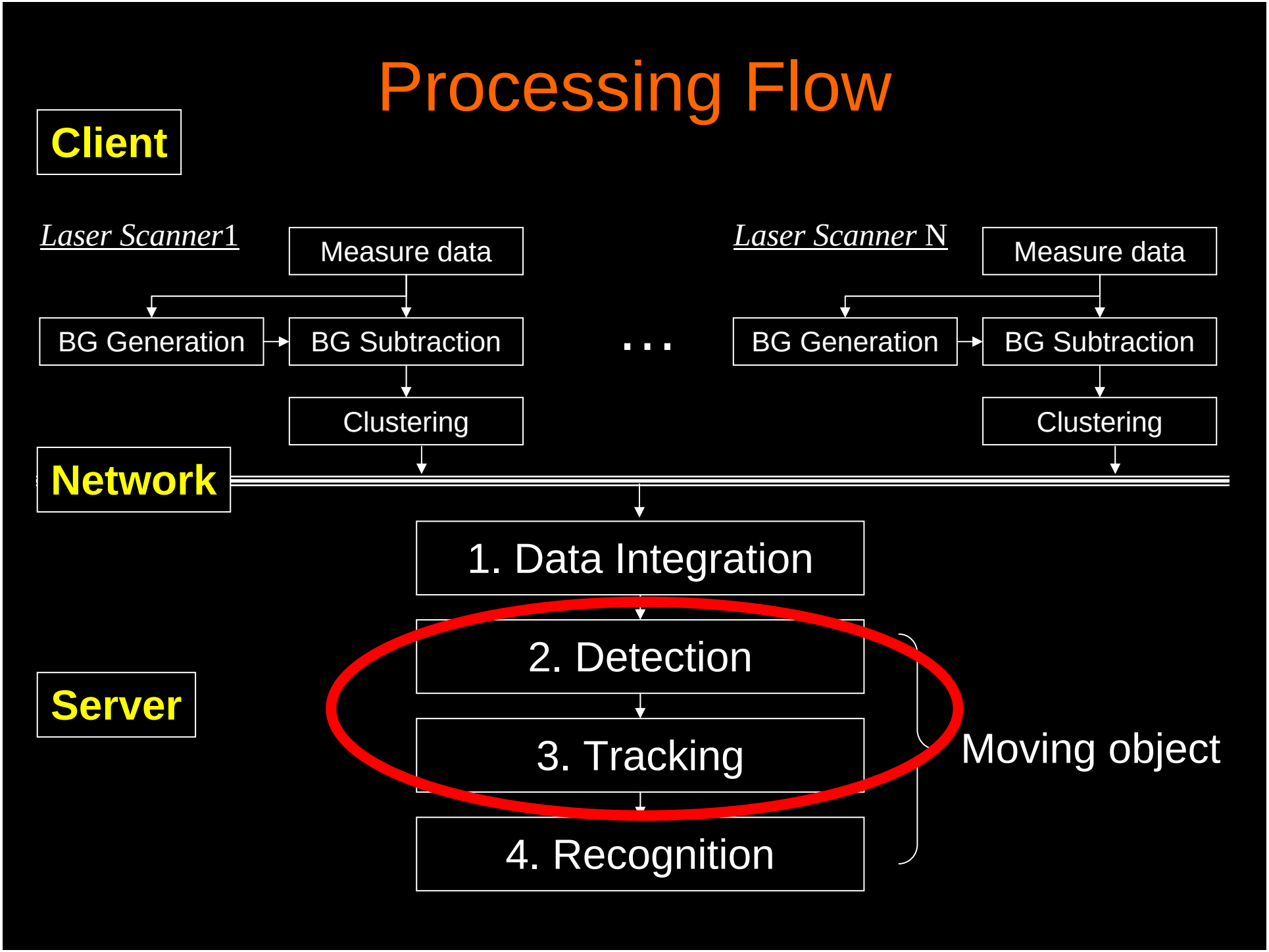



Road side
LD3
LD1
Road side
Safety zone
Safety zone
LD2
Integrated frame
LD1
Single laser frame
LD3
Single laser frame
10m
LD2
Single laser frame

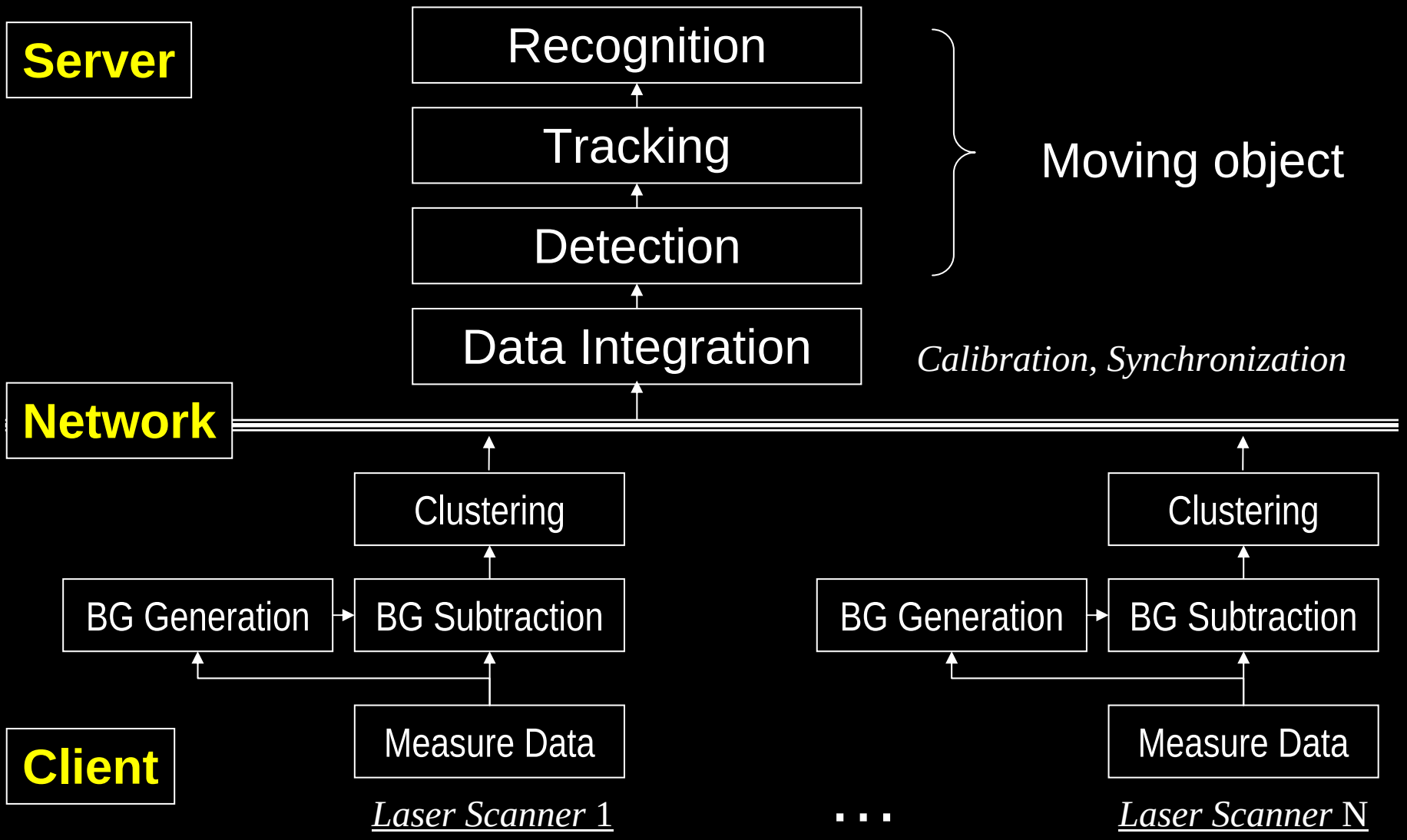

#3
#8
#7
#2
#1
#5

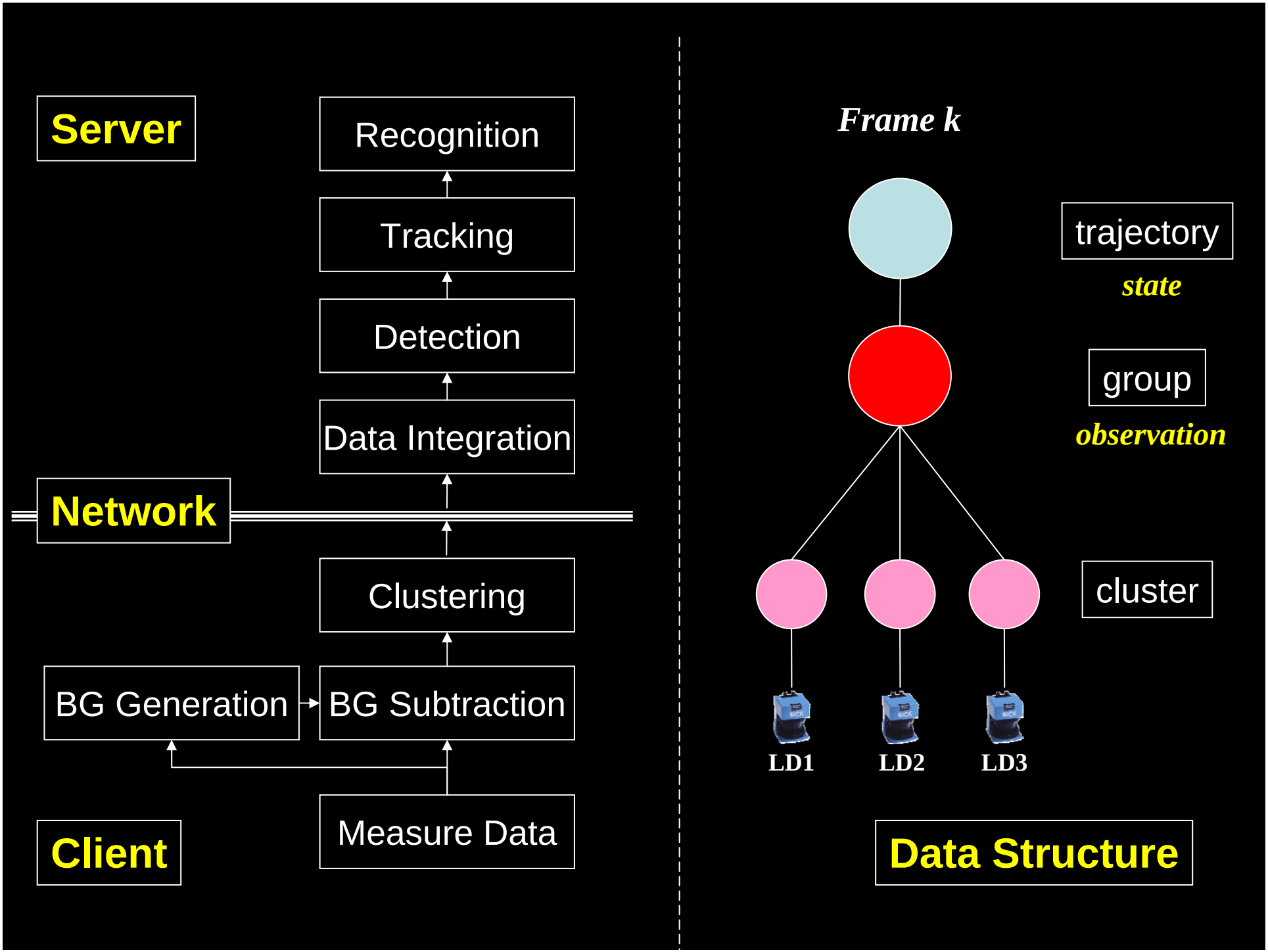

#3
#7
#2
#1
#5

Processing Flow

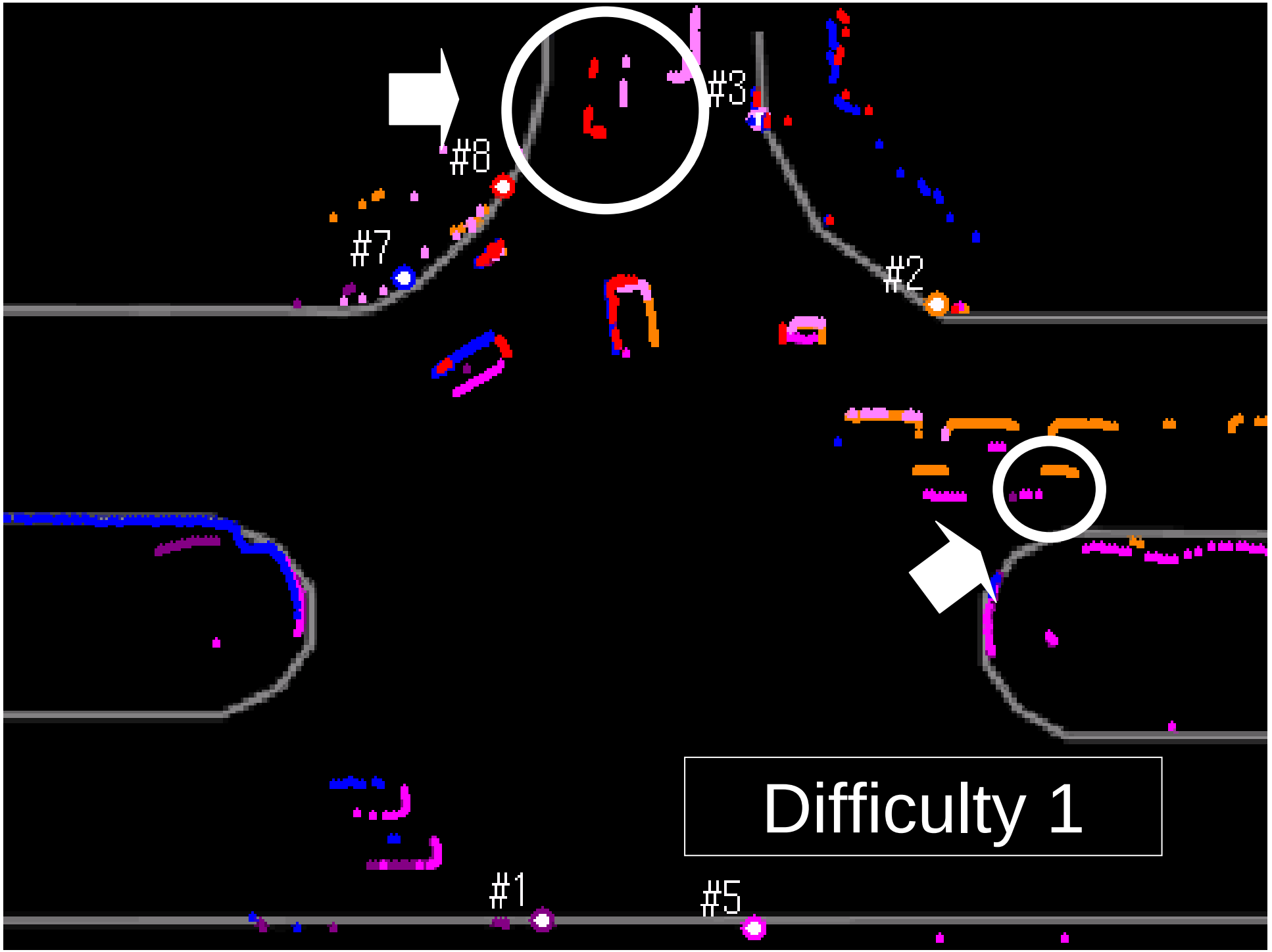


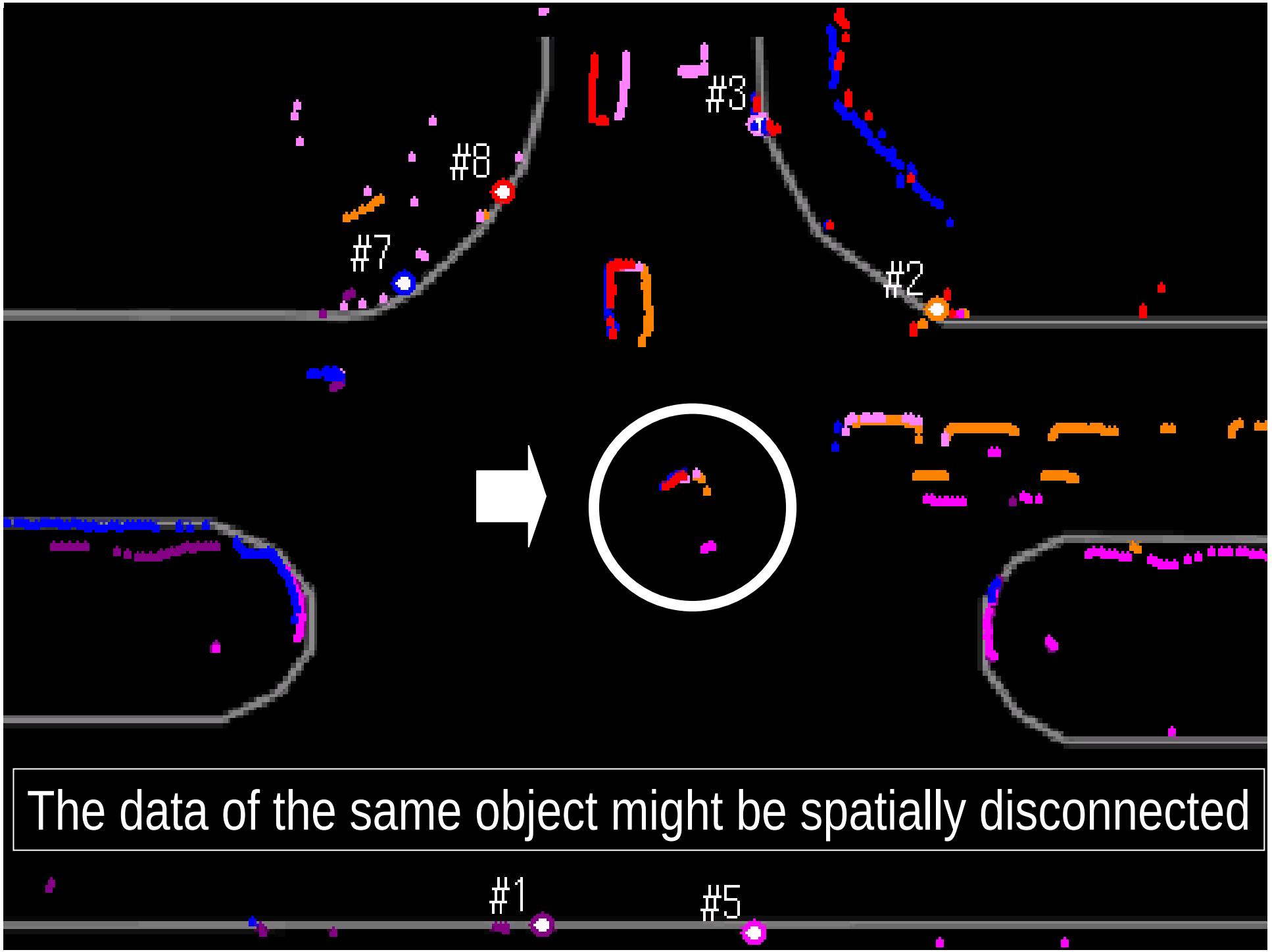
Processing Modules

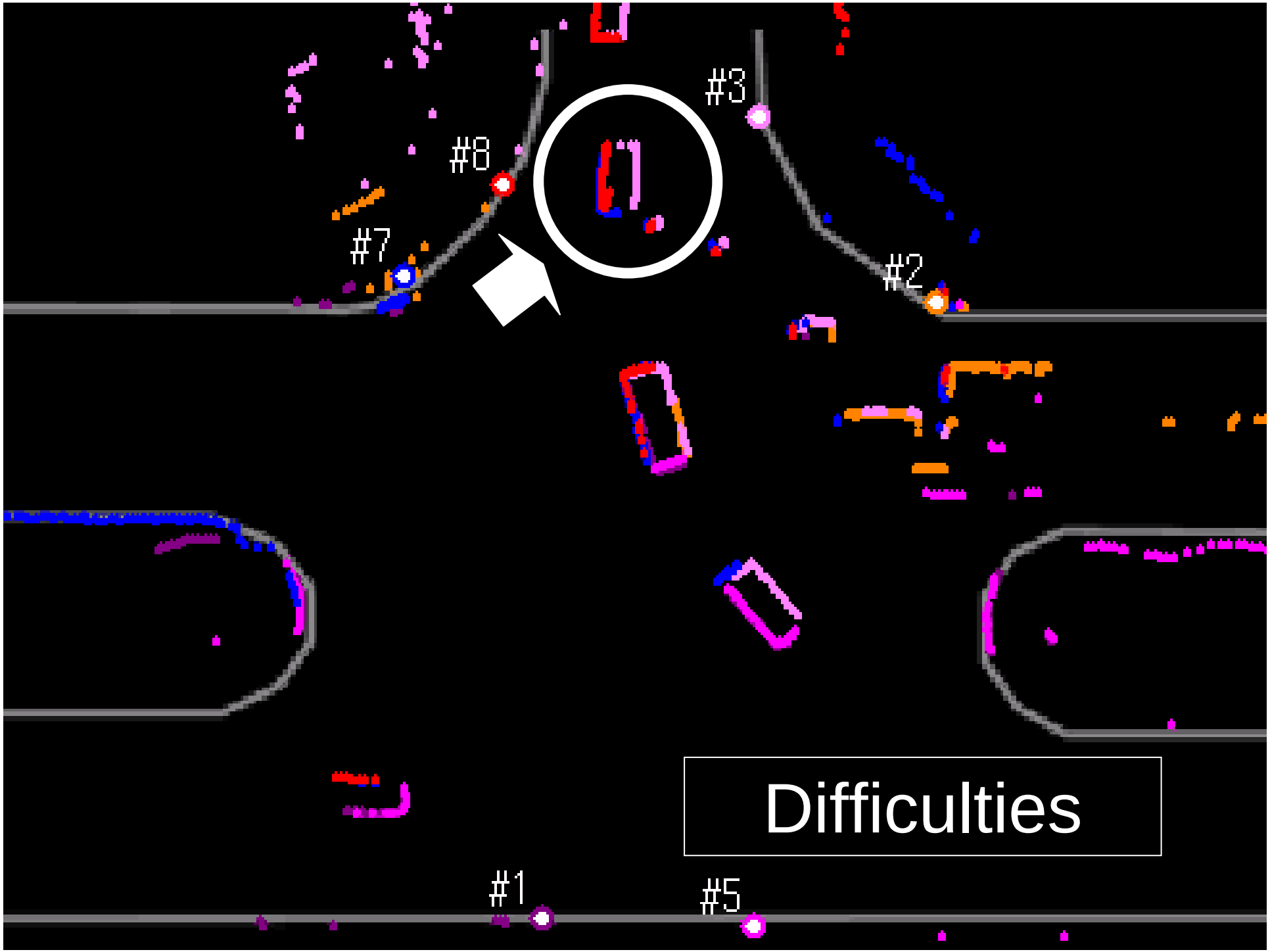


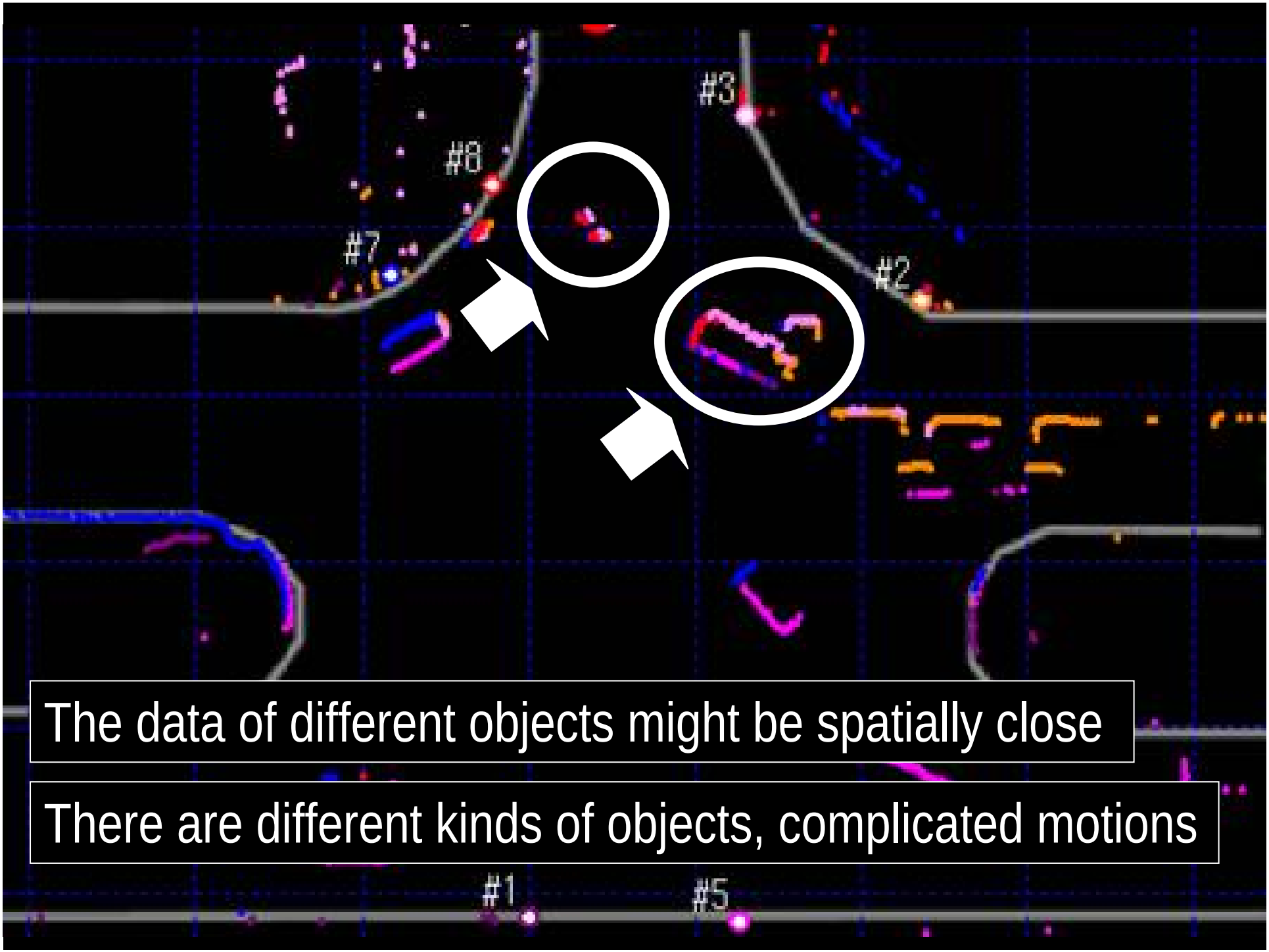

Server
Recognition
Tracking
Detection
Data Integration
Network
Clustering
BG Generation
BG Subtraction
Measure Data
Client
Frame k
trajectory
state
group
observation
cluster
LD1
LD2
LD3
Data Structure


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


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


#3
#8
#7
#2
#1
#5
The data of the same object might be spatially disconnected


#3
#8
#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

Task 1

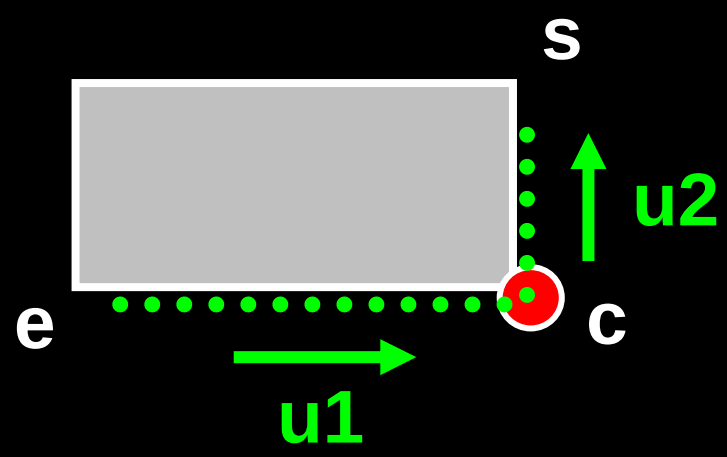
Spatial Data Association

We are not able to rely only on distance, size, shape, location etc for detection and traction.

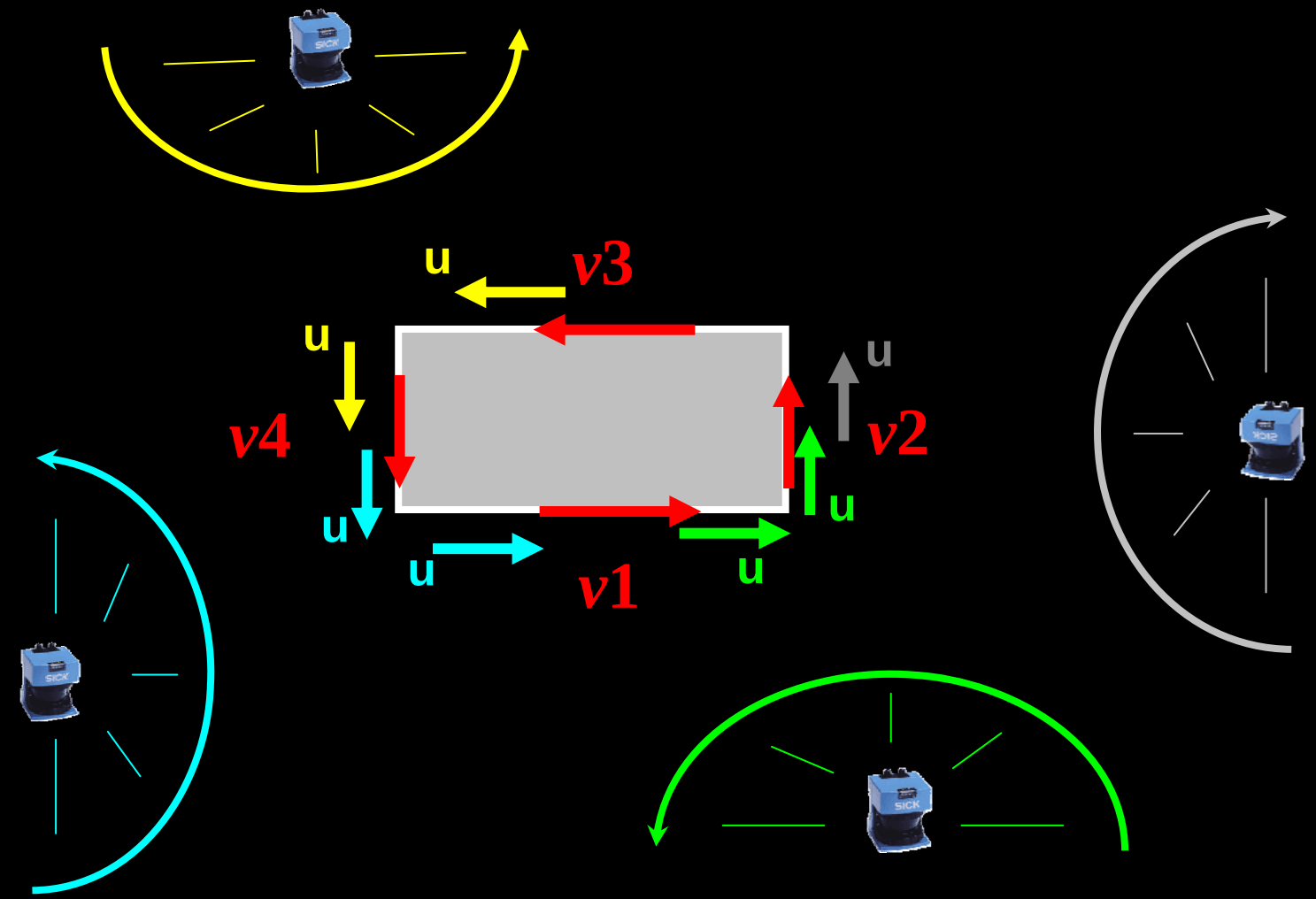
We need to find some other clues to associate the data of the same object together.

Data Feature

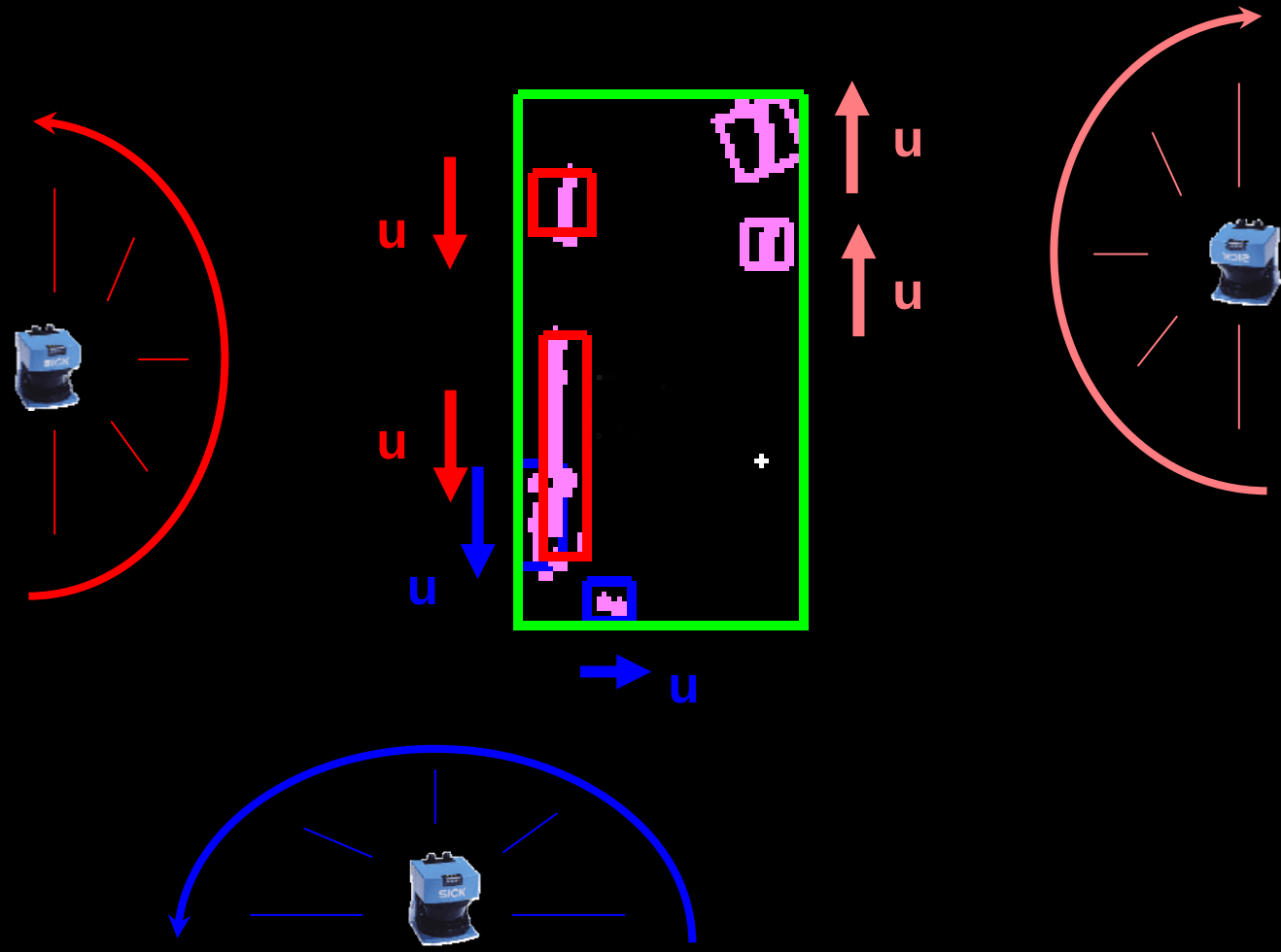
A car



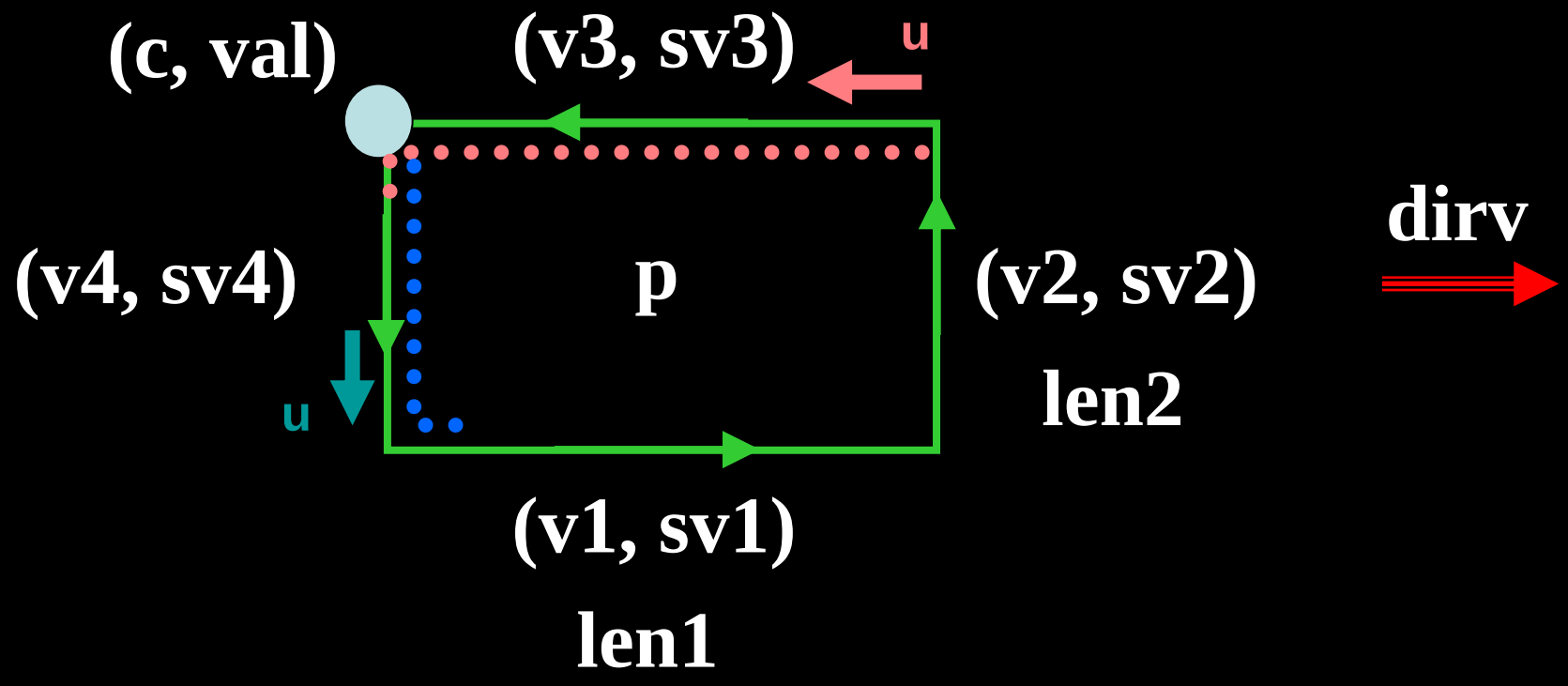
Data Feature



Data Feature



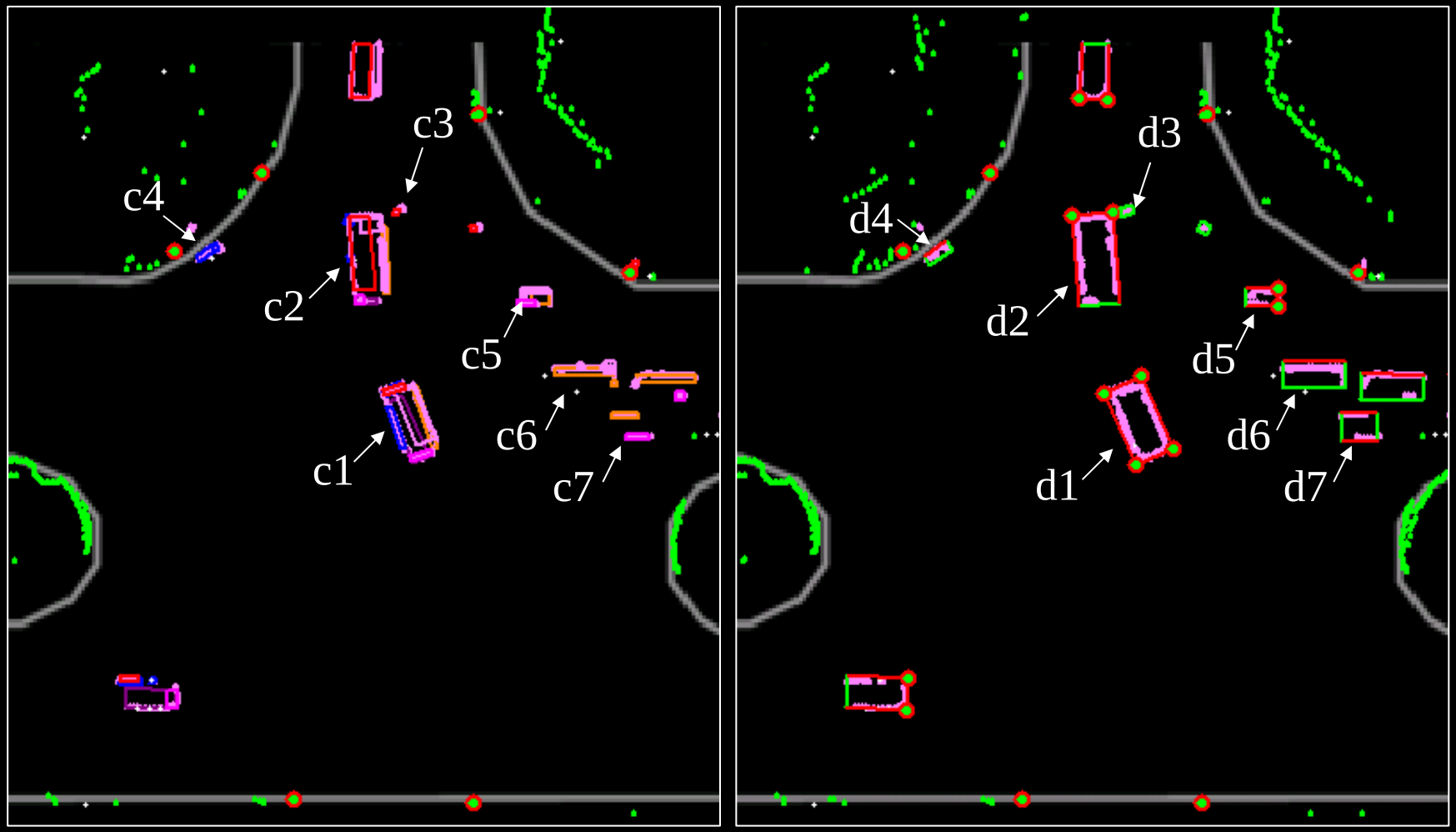
Object Model



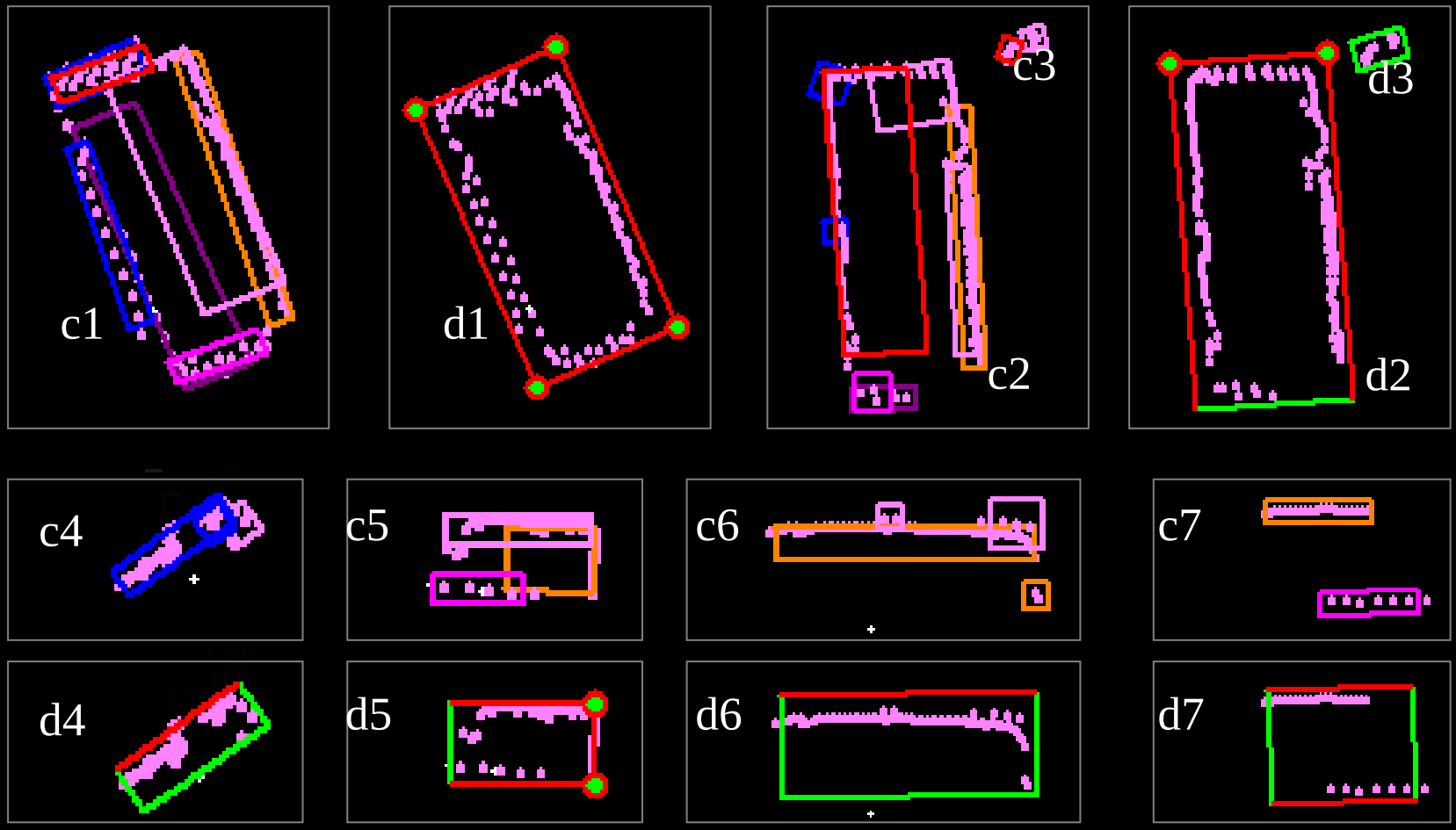
Feature parameters
and their reliabilities

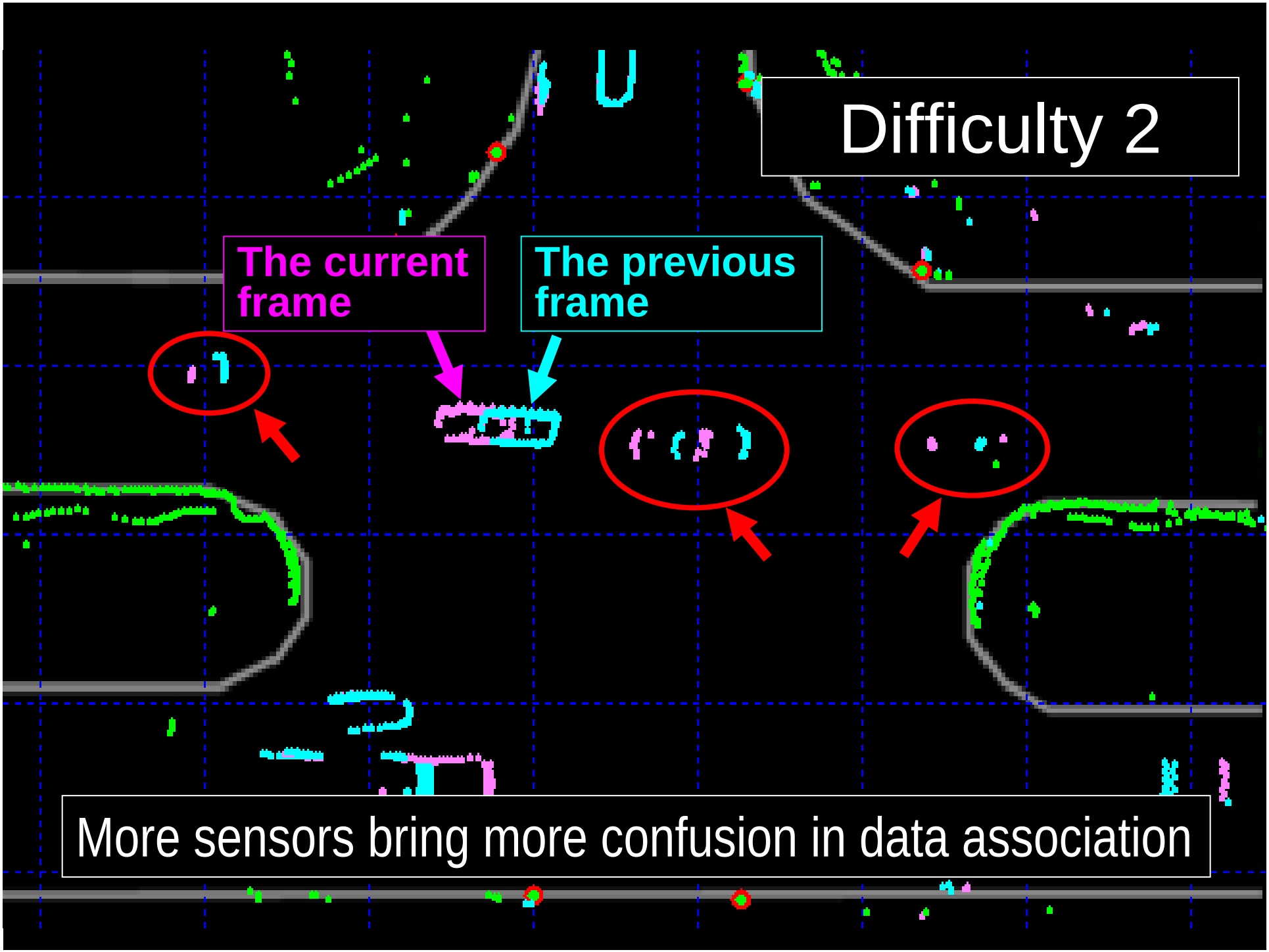
(v1=dirv)

Object Detection Results



Object Detection Results




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

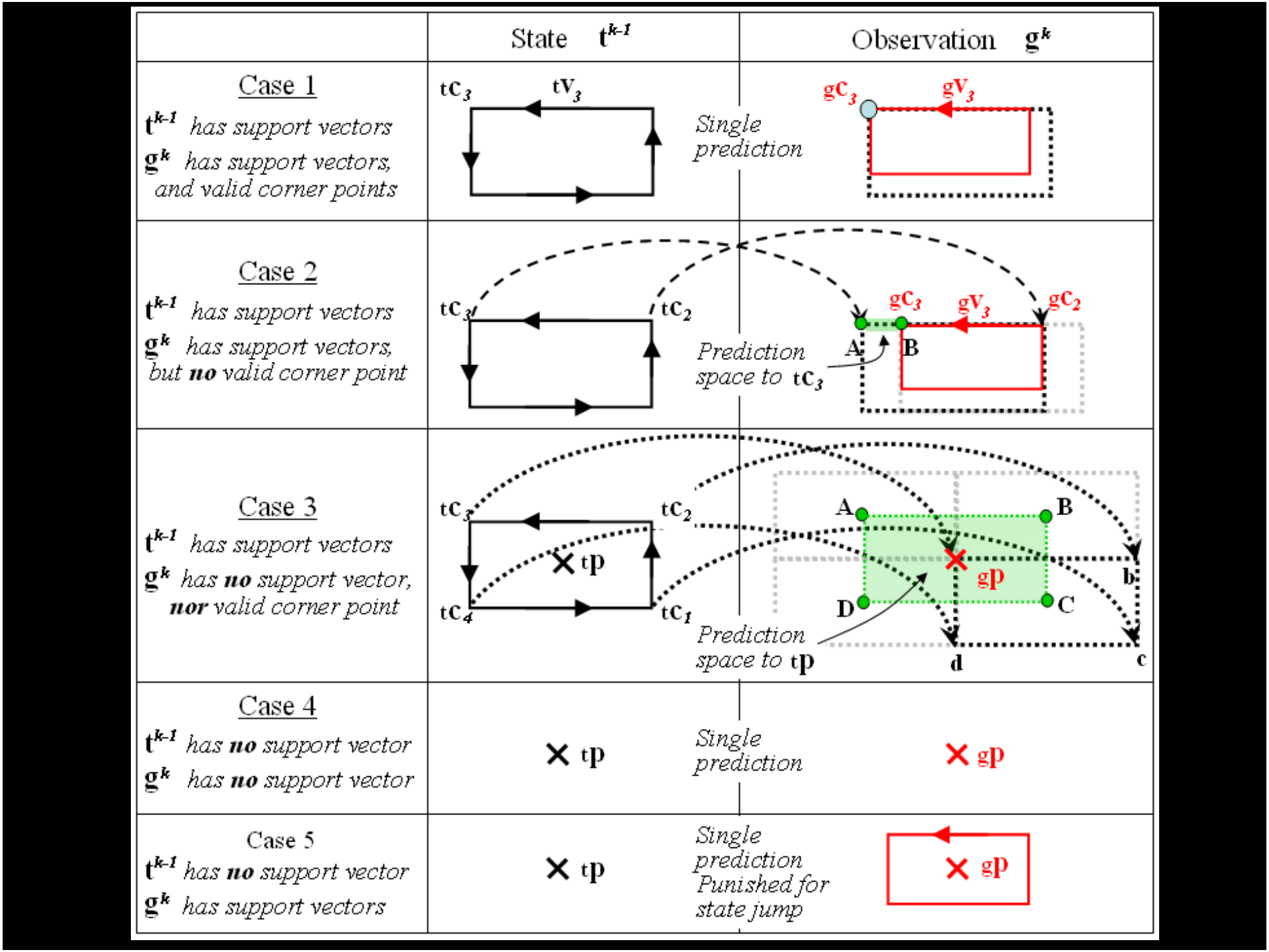
Task 2

Temporal Data Association

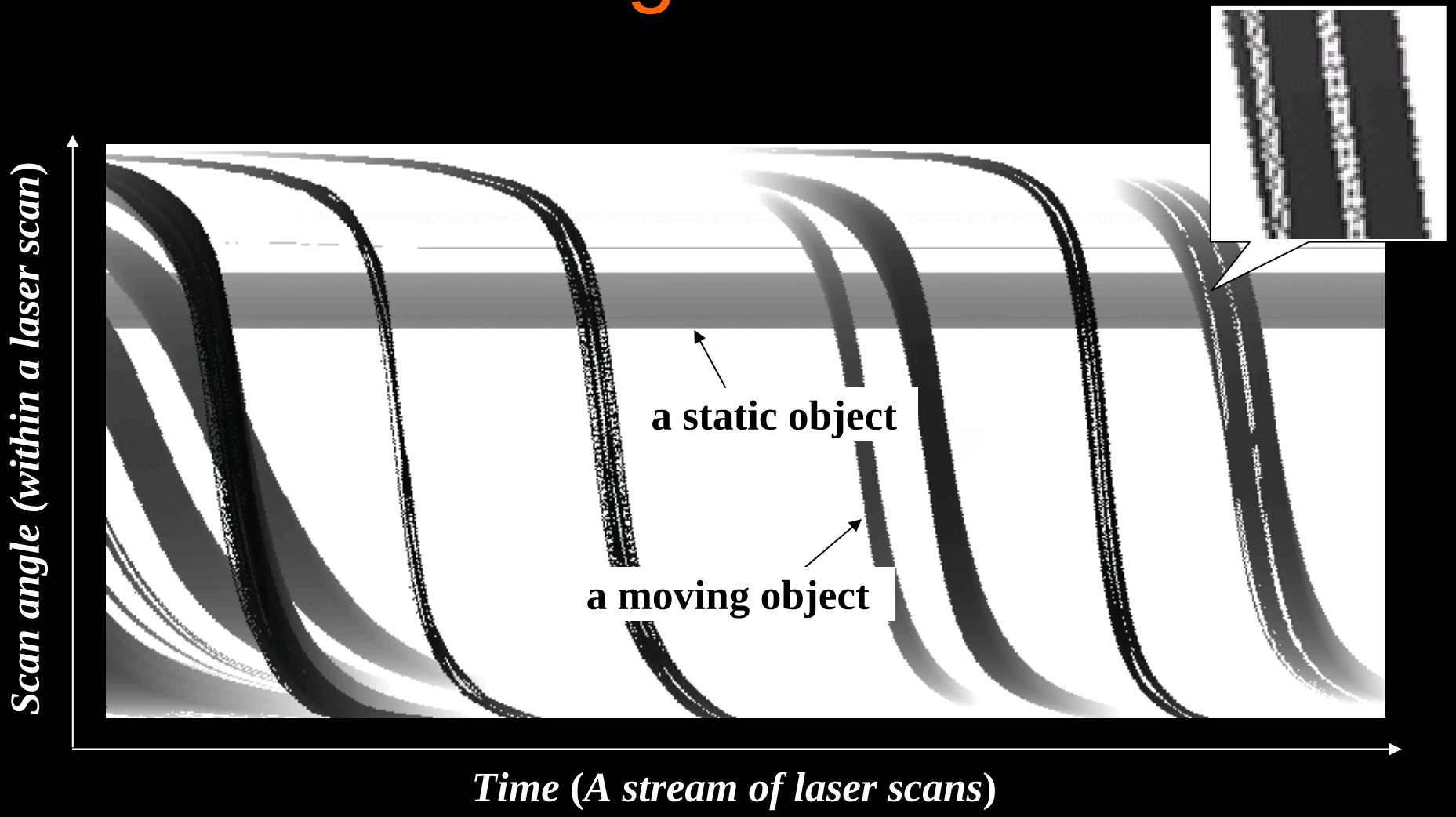
Data association is difficult when facing a complicated environment such as an intersection, where different kinds of objects, different motion patterns exist.

Also, a large number of distributed sensors will bring more difficulties in data association.

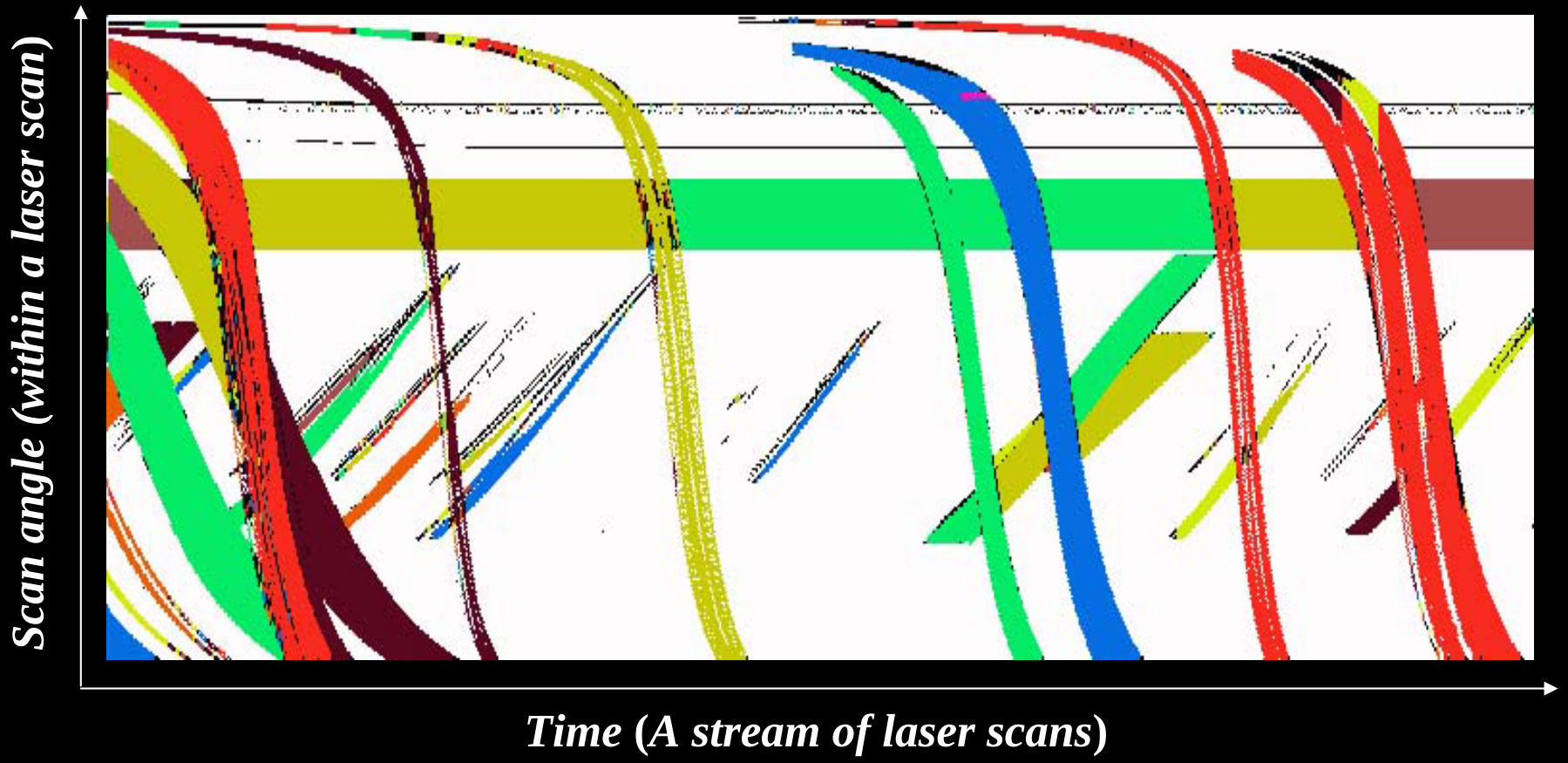
A data association algorithm is required to tackle the confusions.


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
tp
tc_4
tc_1
Prediction space to tp
A
B
D
C
gp
b
d
c
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

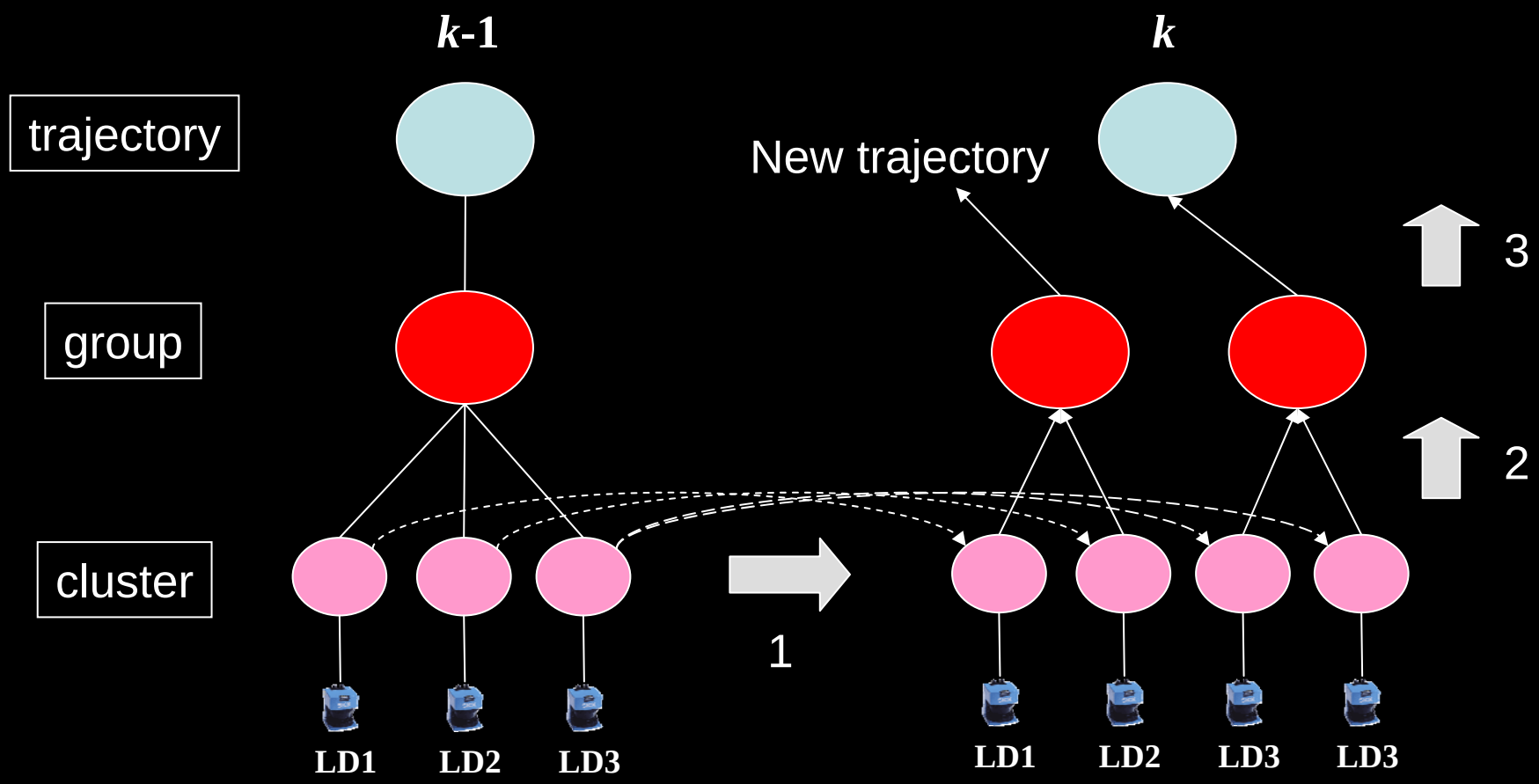
A range stream



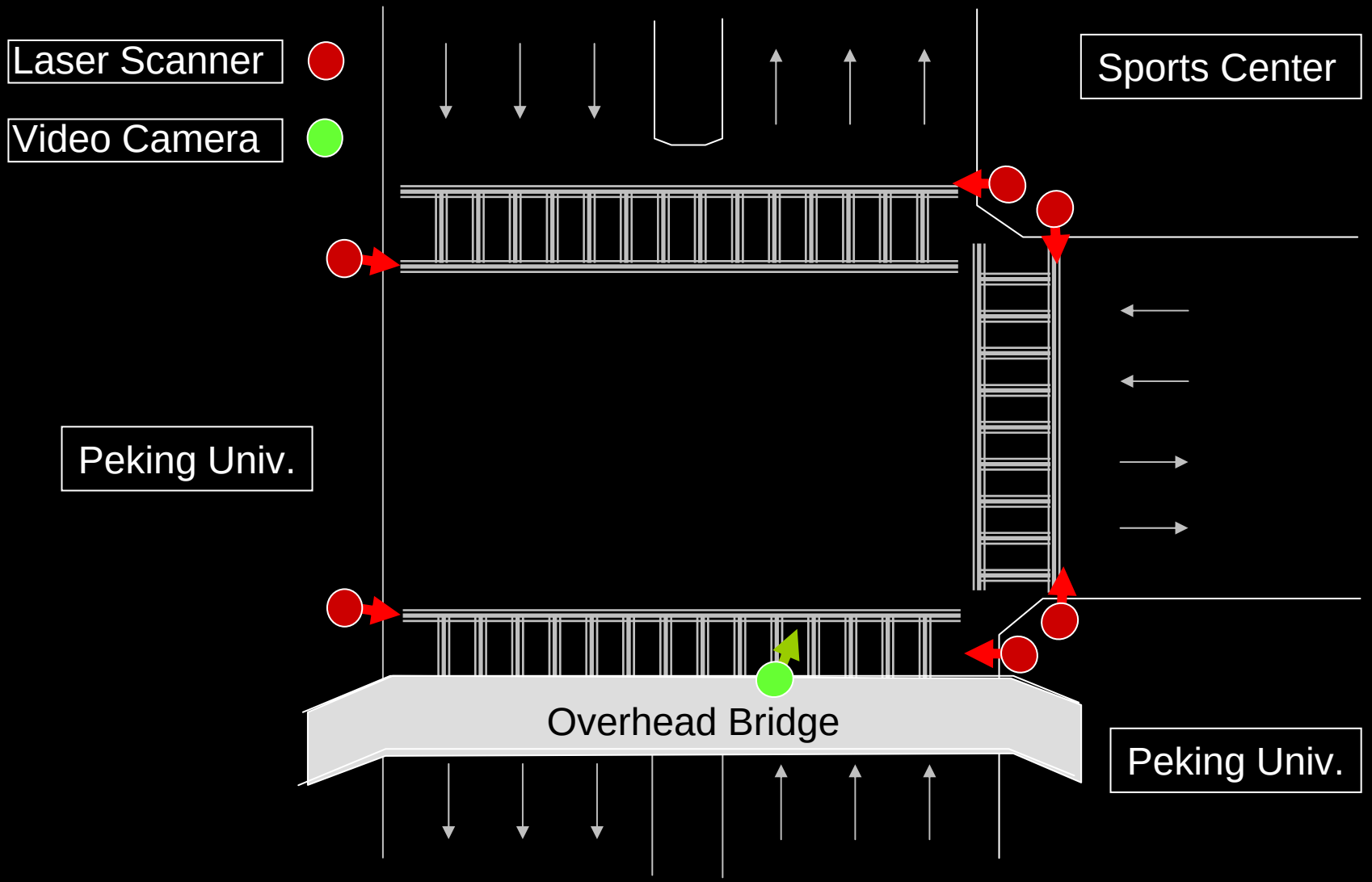
A simple clustering result

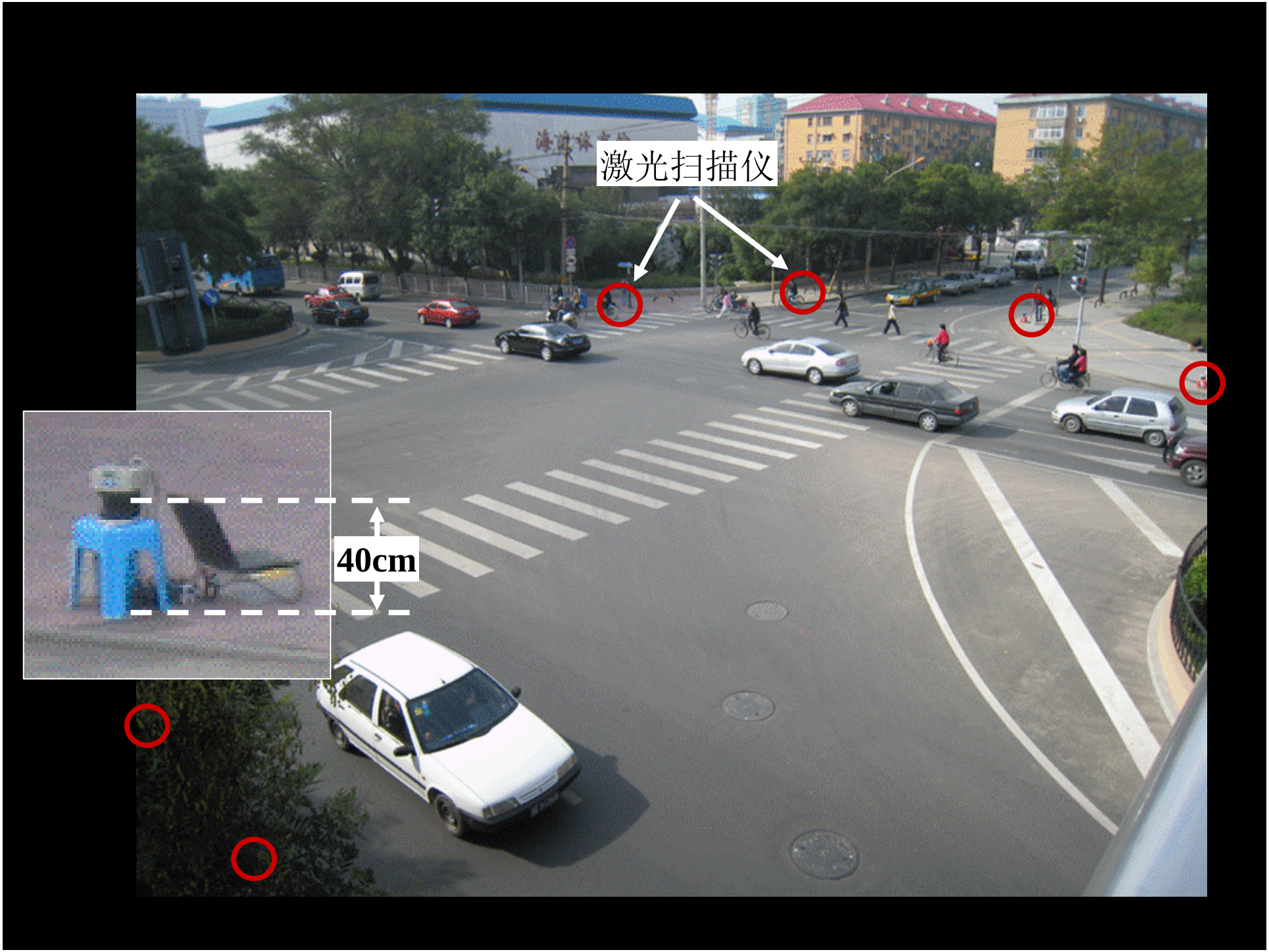


Data Association Method

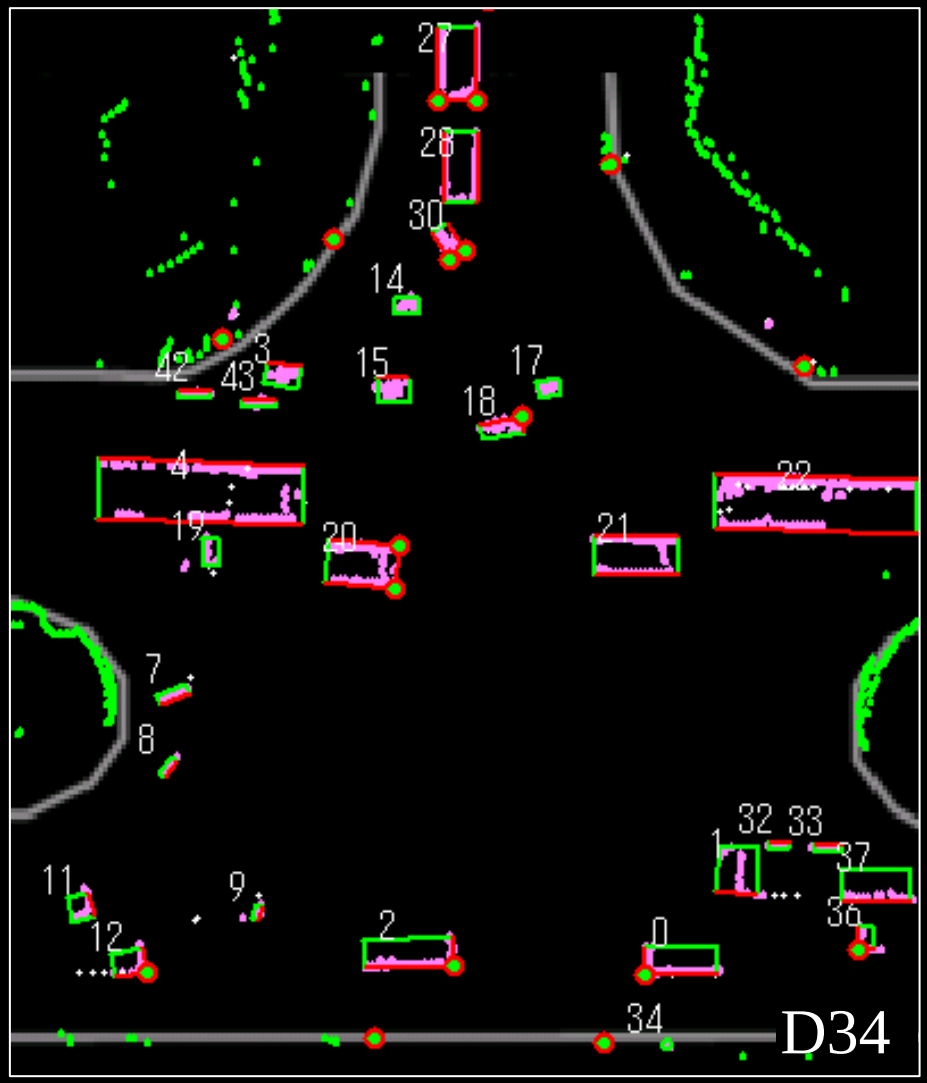


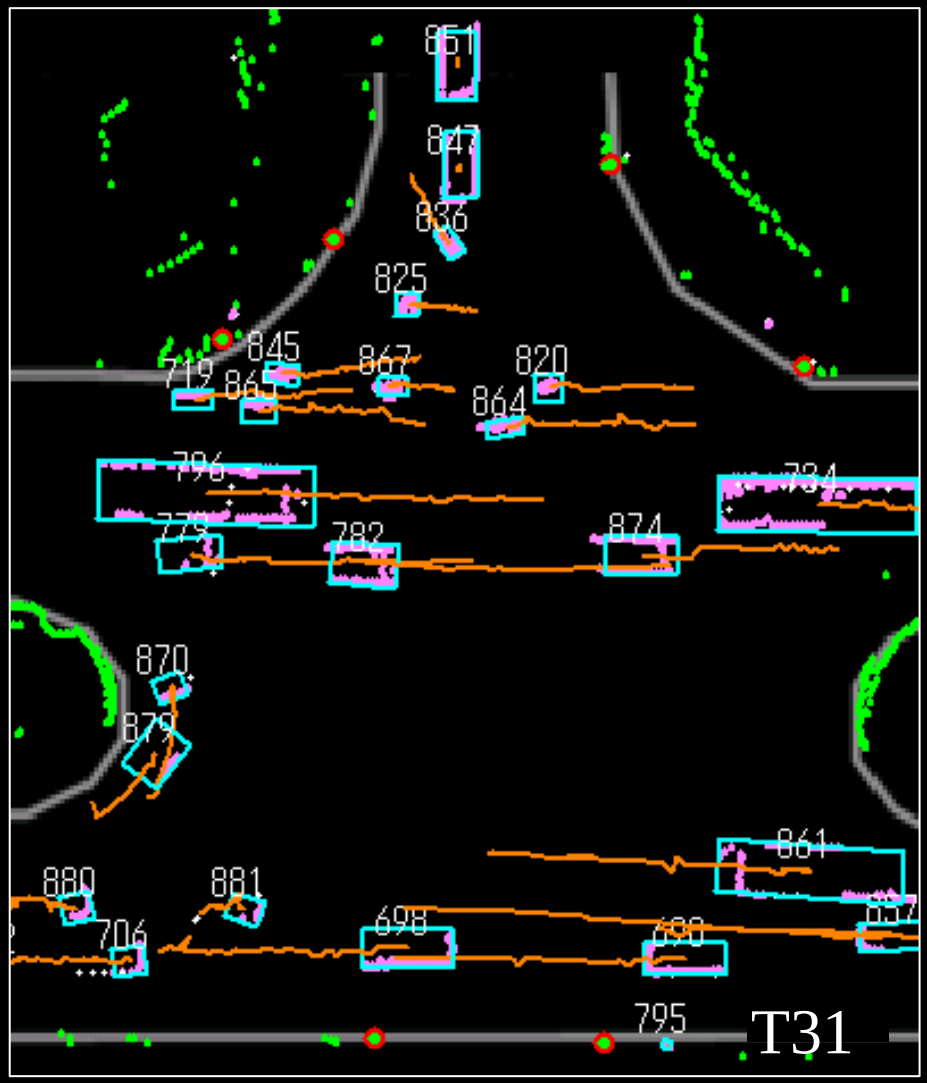
Experiment


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

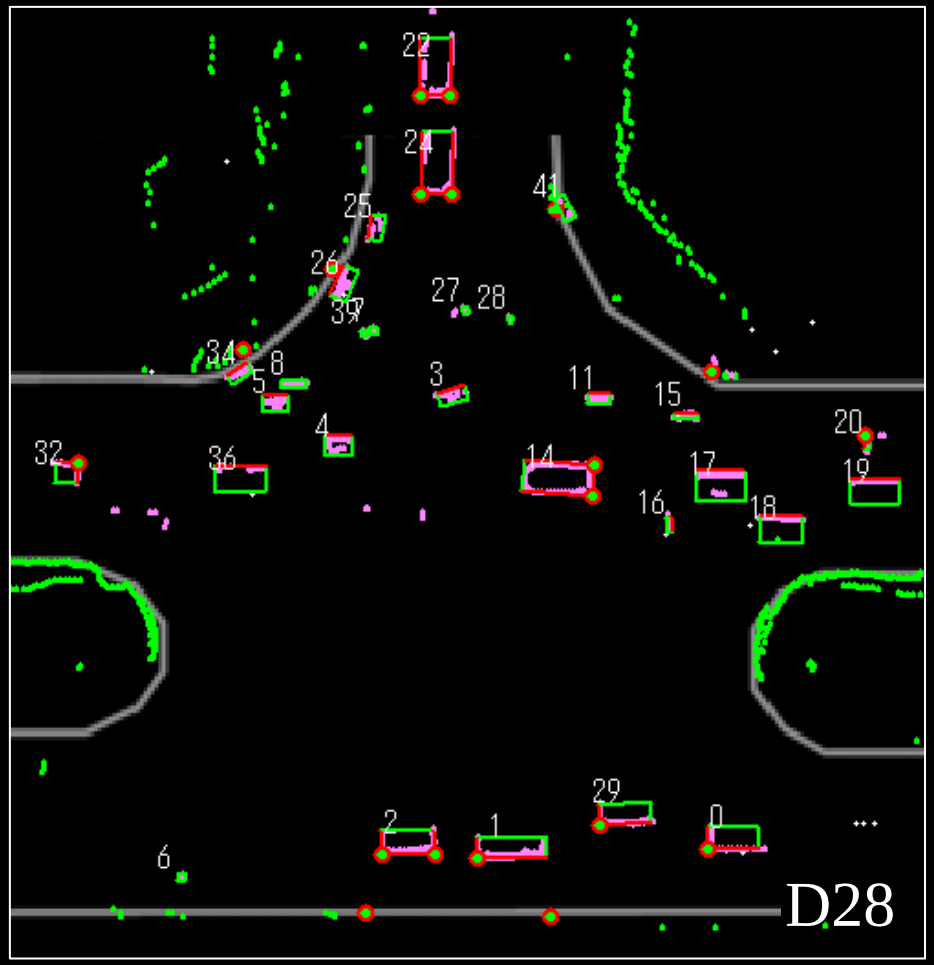

激光扫描仪
40cm

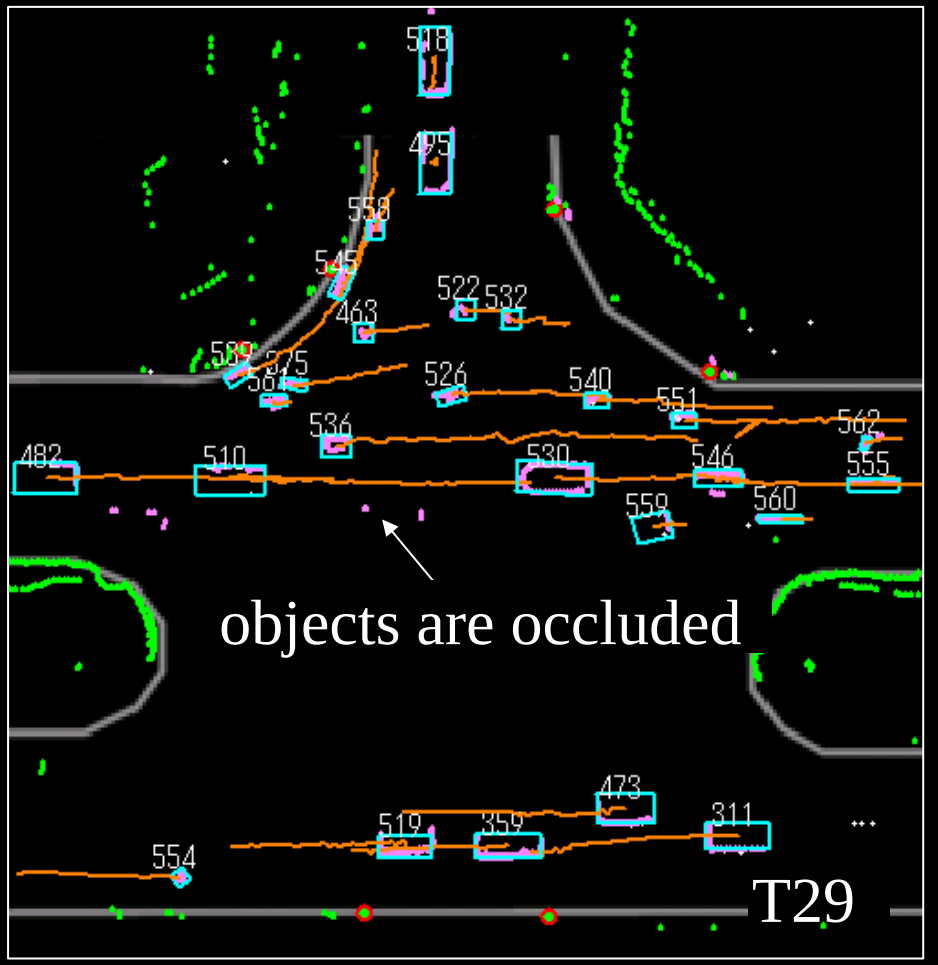
Results

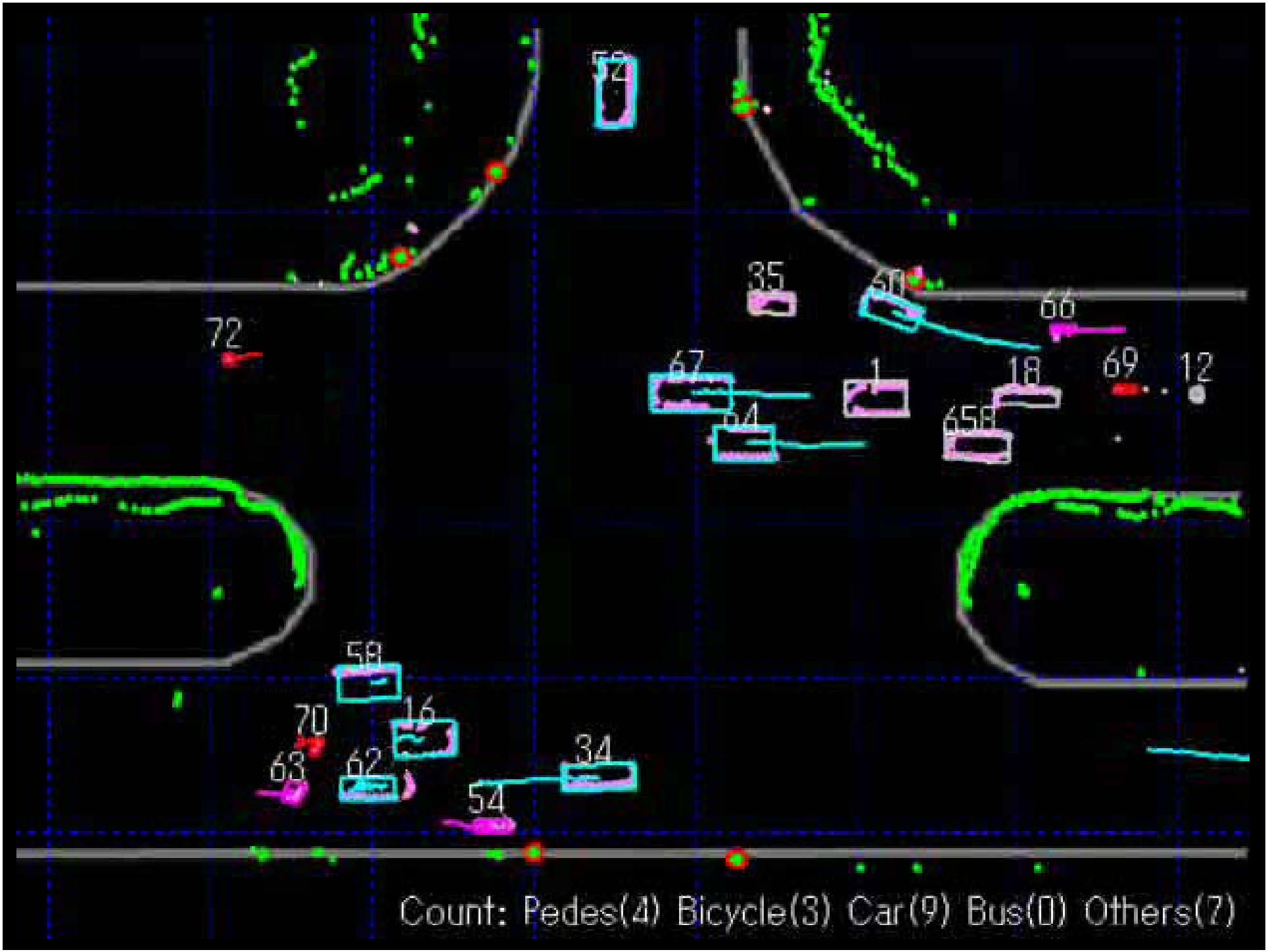


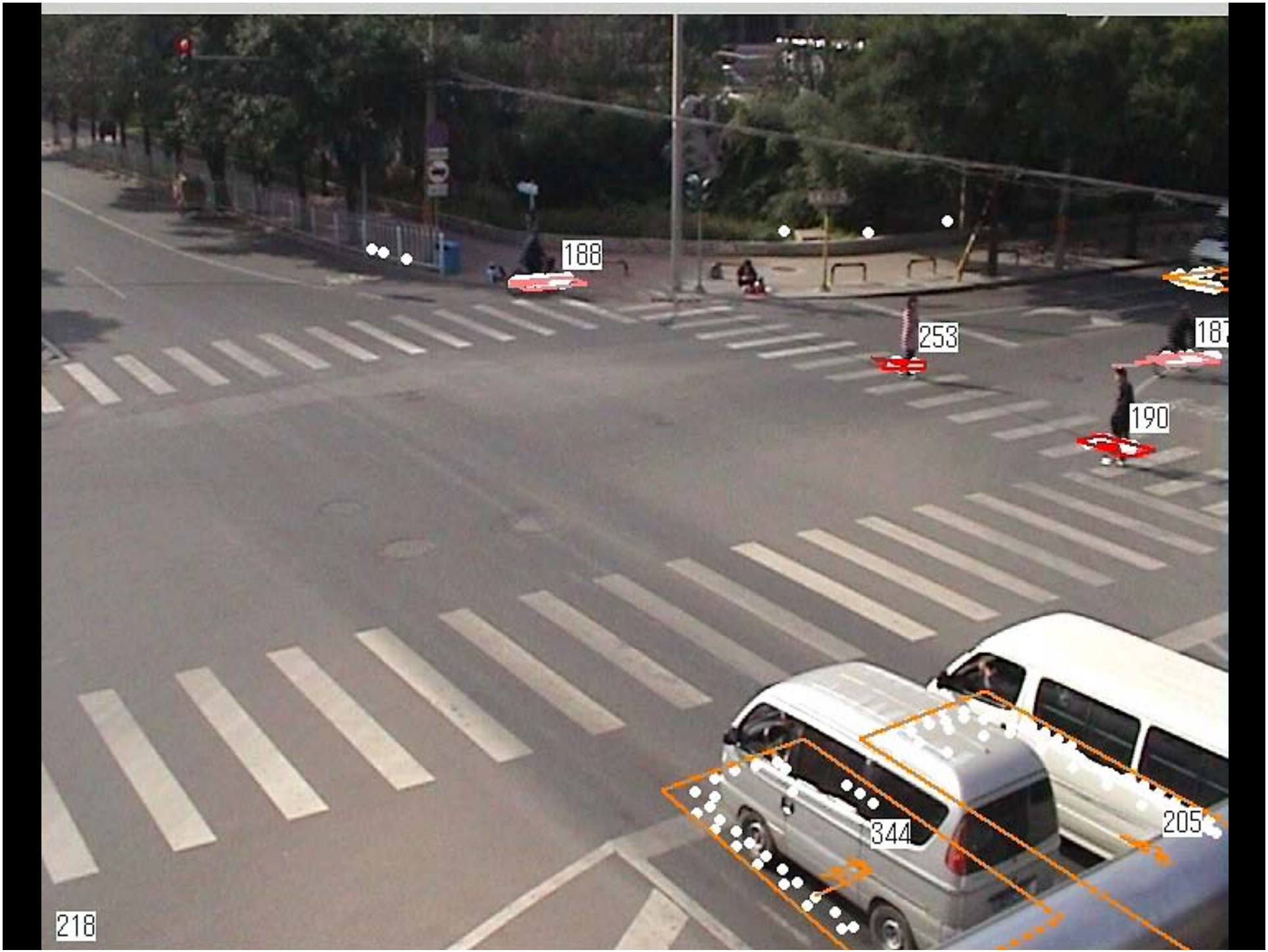


Results



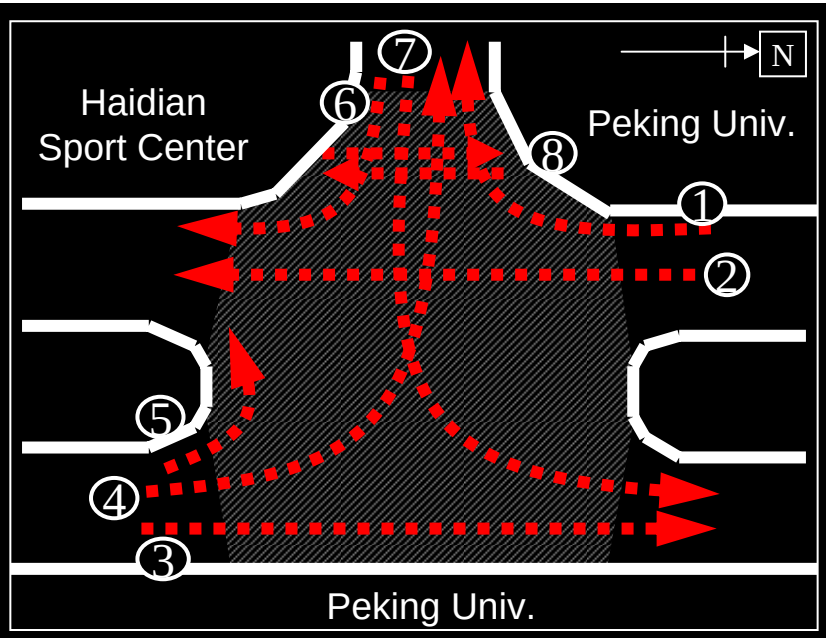



72
35
66
67
1
18
69
12
64
58
70
16
63
62
34
54
Count: Pedes(4) Bicycle(3) Car(9) Bus(0) Others(7)


188
253
190
344
205
218

Accuracy

2007.10.13, 10:00-10:20



主要模式	移动目标类型	完整	中断1次	中断多次	合并分裂交叉	移动目标总数	轨迹错误数	轨迹错误率	不完全轨迹数	不完全轨迹率
模式1	非机动车	12	0	0	3	15	3	20%	3	20%
	机动车	37	1	0	0	38	0	0%	1	3%
模式2	非机动车	107	1	1	8	117	8	7%	10	9%
	机动车	240	12	0	7	259	7	3%	19	7%
模式3	非机动车	69	1	1	3	74	3	4%	5	7%
	机动车	178	0	2	5	185	5	3%	7	4%
模式4	非机动车	31	0	3	1	35	1	3%	4	11%
	机动车	29	1	0	1	31	1	3%	2	6%
模式5	机动车	9	1	1	1	12	1	8%	3	25%
模式6	非机动车	94	1	0	6	101	6	6%	7	7%
	机动车	85	1	0	3	89	3	3%	4	4%
模式7	非机动车	9	0	0	0	9	0	0%	0	0%
	机动车	58	2	1	0	61	0	0%	3	5%
模式8	行人	30	1	1	5	37	5	14%	7	19%

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

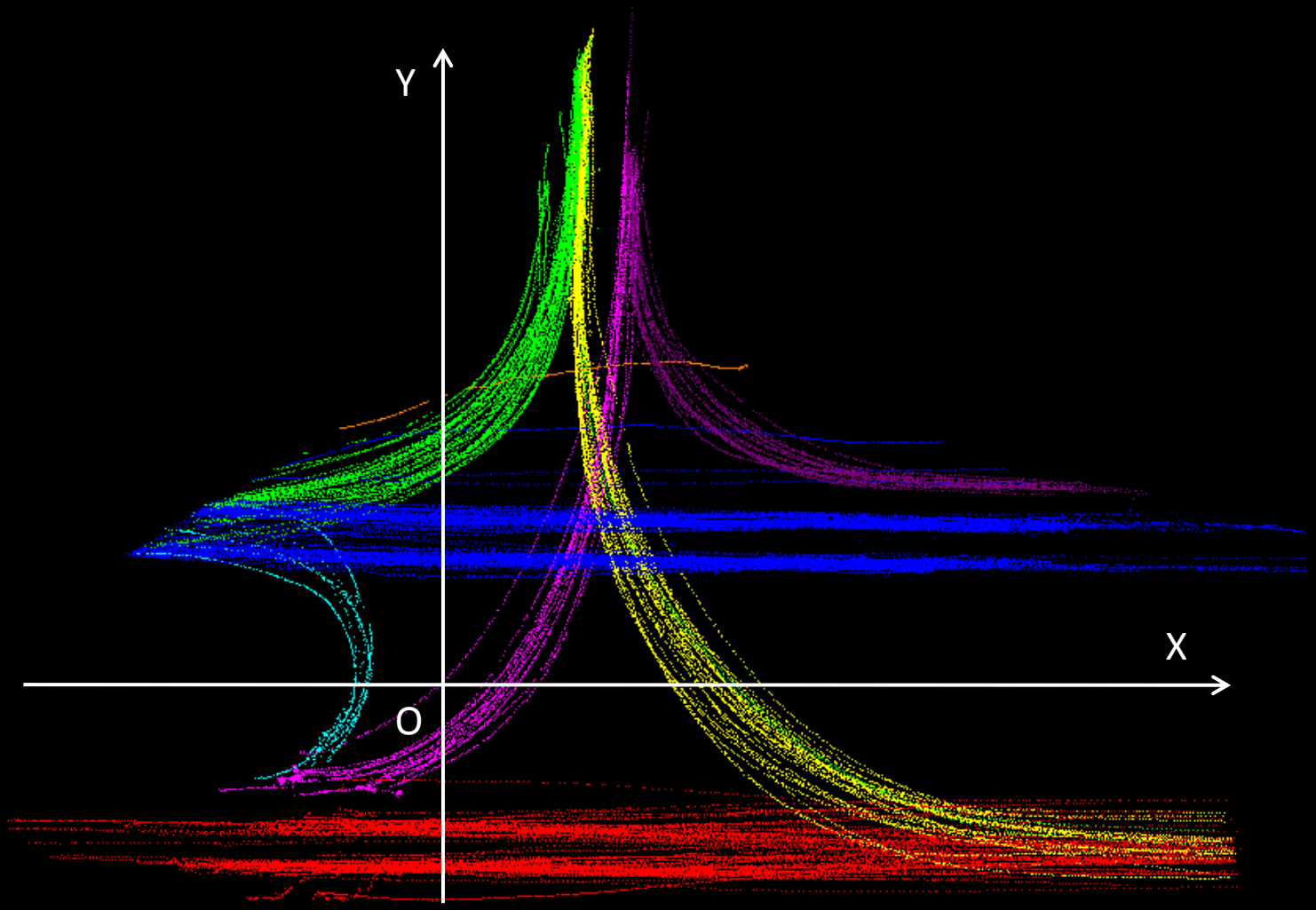
Accuracy Analysis

2007.10.13, 10:00-10:20

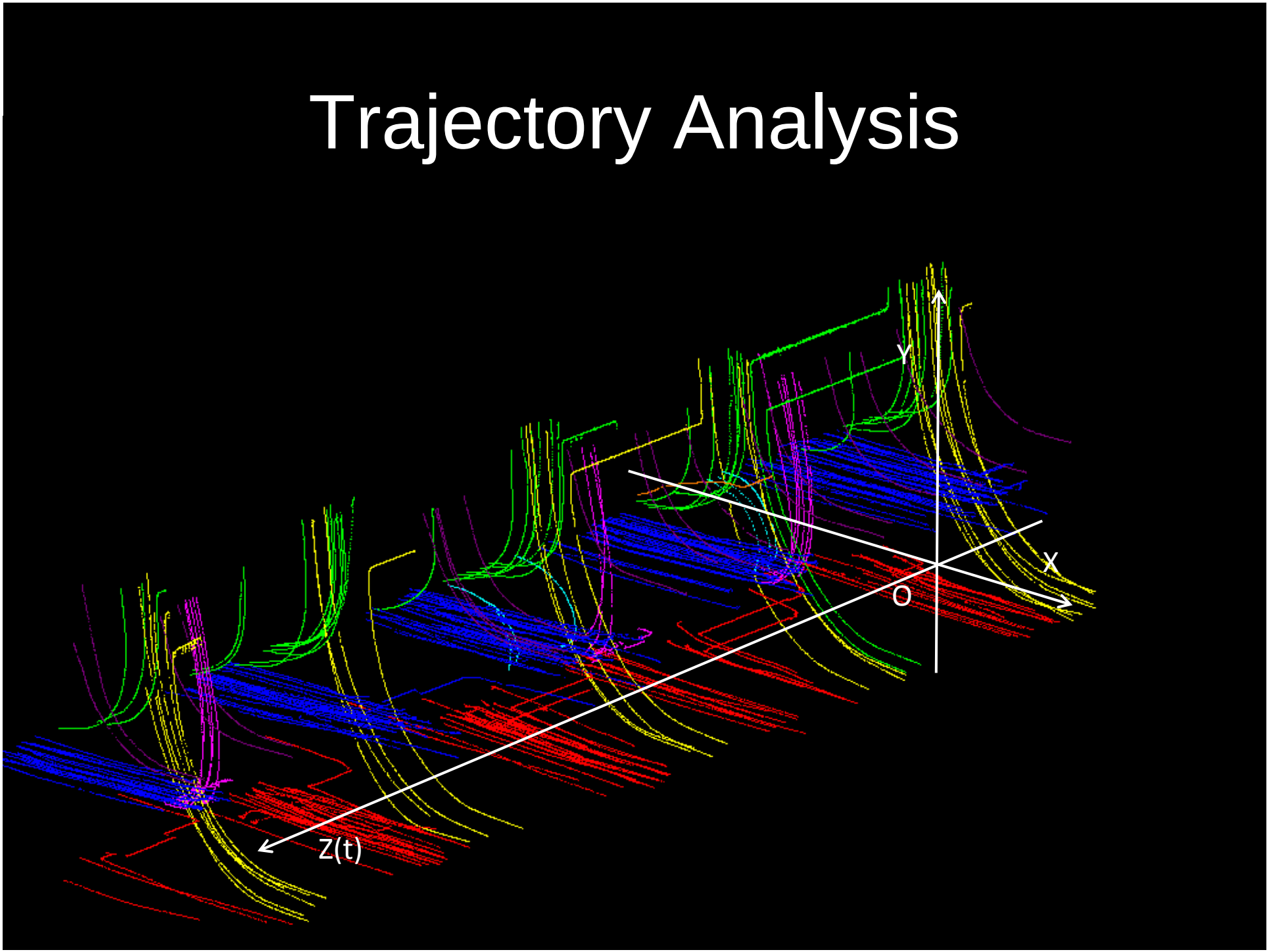
移动目标类型	完整	中断1次	中断多次	合并分裂交叉	移动目标总数	轨迹错误数	轨迹错误率	不完全轨迹数	不完全轨迹率
行人	30	1	1	5	37	5	14%	7	19%
非机动车	322	3	5	21	351	21	6%	29	8%
机动车	636	18	4	17	675	17	3%	39	6%
总计	988	22	10	43	1063	43	4%	75	7%

错误分类 / 真实类型	行人	非机动车	机动车	物体总数	分类错误率
行人	0	0	0	37	0.00%
非机动车	13	0	22	351	9.97%
机动车	6	7	0	675	1.9%

Trajectory Analysis

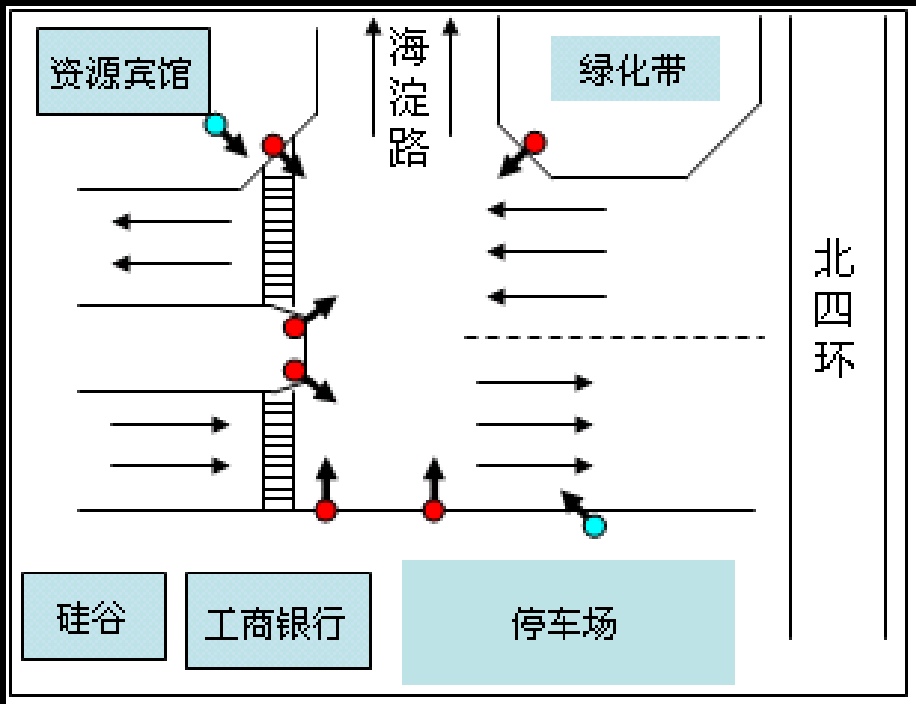


Trajectory Analysis

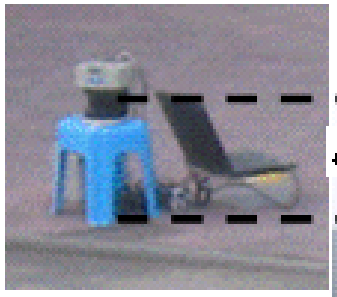


海淀桥北交叉口实验

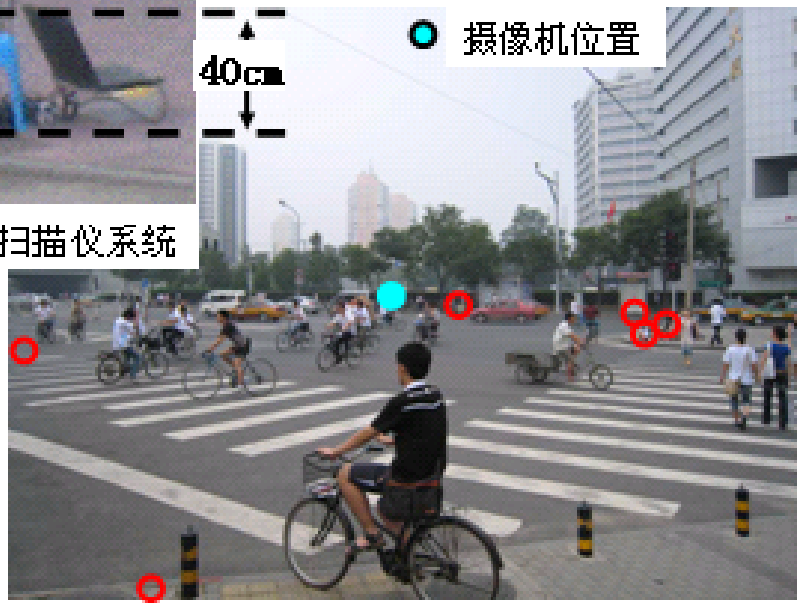
日期：2008年7月16日，时间：6：00-21：00
日期：2008年7月22日，时间：6：00-21：00



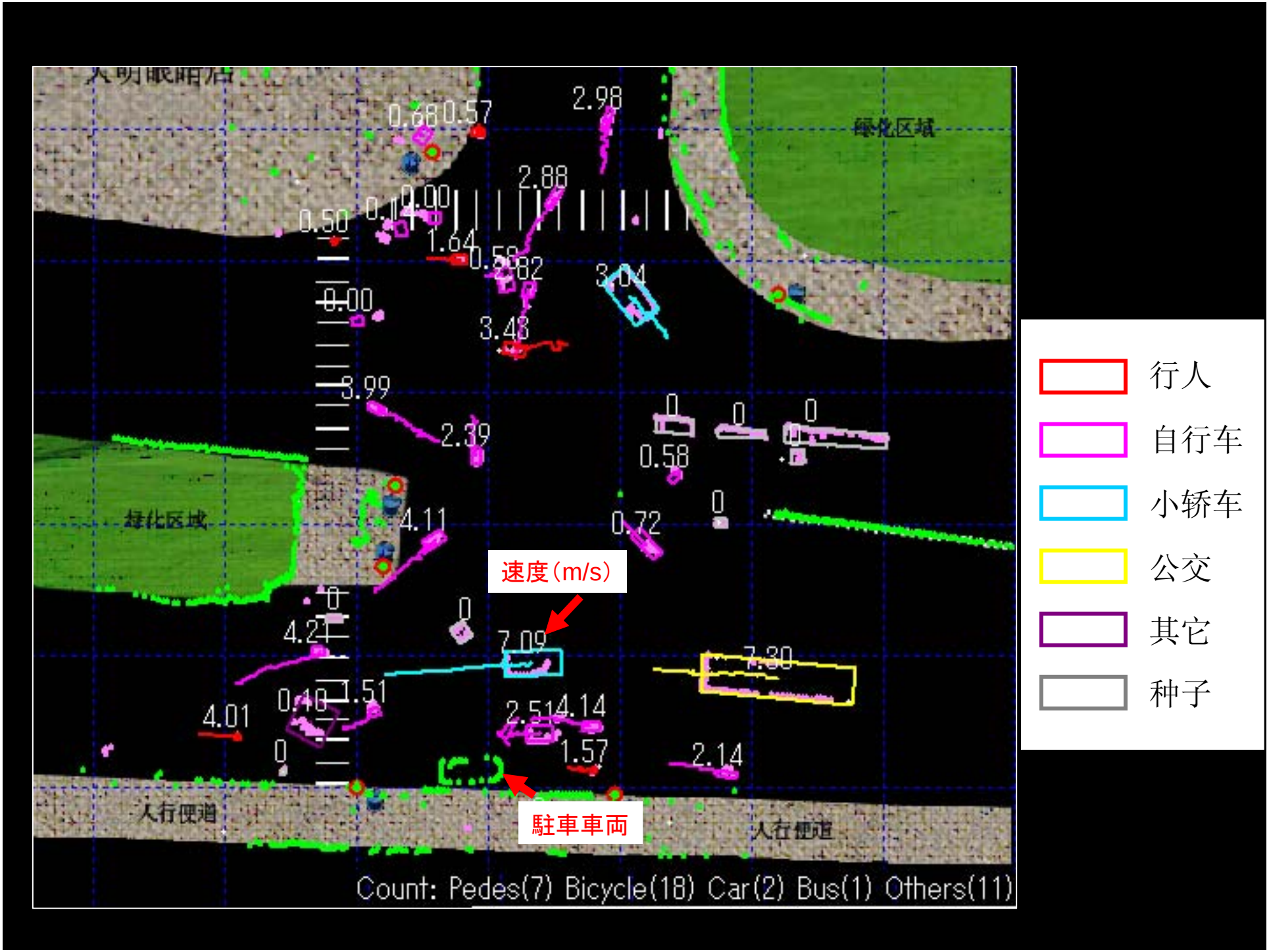
传感器分布平面图



1套激光扫描仪系统

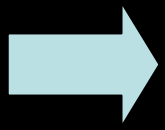


实地照片


绿化区域
绿化区域
人行便道
人行便道
速度(m/s)
駐車車両
Count: Pedes(7) Bicycle(18) Car(2) Bus(1) Others(11)
行人
自行车
小轿车
公交
其它
种子

移动目标轨迹数据

分布式激光数据
*-s.lms1
*-s.lms2
...
*-s.lms6



轨迹数据
*.traj

```
#trajectory,no,class,length,width,svcnt
#class={0:people;1:bicycle;2:car;3:bus;4:something else}
#frameno,millisec,trajpx,trajpy,grpx,grpy,tdirvx,tdirvy,dirvx,dirvy,tspeed,speed,....

trajectory,6,1,1.0,0.4,1
043,48.539,0.043,48.539,0.198,0.980,0.000,-0.003,0.000,3.294,0.956,0.29
043,48.542,0.043,48.542,0.198,0.980,0.046,0.195,0.000,3.532,0.950,0.313,
003,48.348,0.542,0.193,0.98 0.191,0.000,3.24 0.29
14,68400476,-0.003,48.351,0.546,0.000,0.00 0.195,0.000,7.54 0.31
....
trajectory,3,2,3.2
24,68400743,18.908,18.908,6.778,0.978,0.207,0.000,0.000,0.000,4.160,0.990,-0.14
23,68400716,19.942,6.863,19.942,6.863,0.978,0.207,0.173,0.013,0.000,4.352,0.966,0.260,
22,68400690,19.769,6.850,19.769,6.850,0.976,0.217,0.000,0.000,0.000,4.247,0.986,0.168,
21,68400663,20.613,7.023,20.613,7.023,0.976,0.217,0.000,0.000,0.000,4.462,0.987,0.161,
20,68400637,20.019,7.629,20.237,7.039,0.987,0.161,0.087,-0.087,0.000,4.683,0.987,0.16
....
```

种类，大小

时刻

位置

方向

速度

移动目标轨迹数据

Time	Date		File	PC						Confirm	END	trajectory out
				Npc1	Npc2	Npc3	Npc4	Npc5	Npc6			
06:00-06:50	20080716	06:00	a20080716060000									
	20080716	06:10	a20080716061000									
	20080716	06:20	a20080716062000									
	20080716	06:30	a20080716063000									
	20080716	06:40	a20080716064000									
	20080716	06:50	a20080716065000							O	O	O
07:00-07:50	20080716	07:00	a20080716070000							O	O	O
	20080716	07:10	a20080716071000							O	O	O
	20080716	07:20	a20080716072000							O	O	O
	20080716	07:30	a20080716073000							O	O	O
	20080716	07:40	a20080716074000							O	O	O
	20080716	07:50	a20080716075000							O	O	O

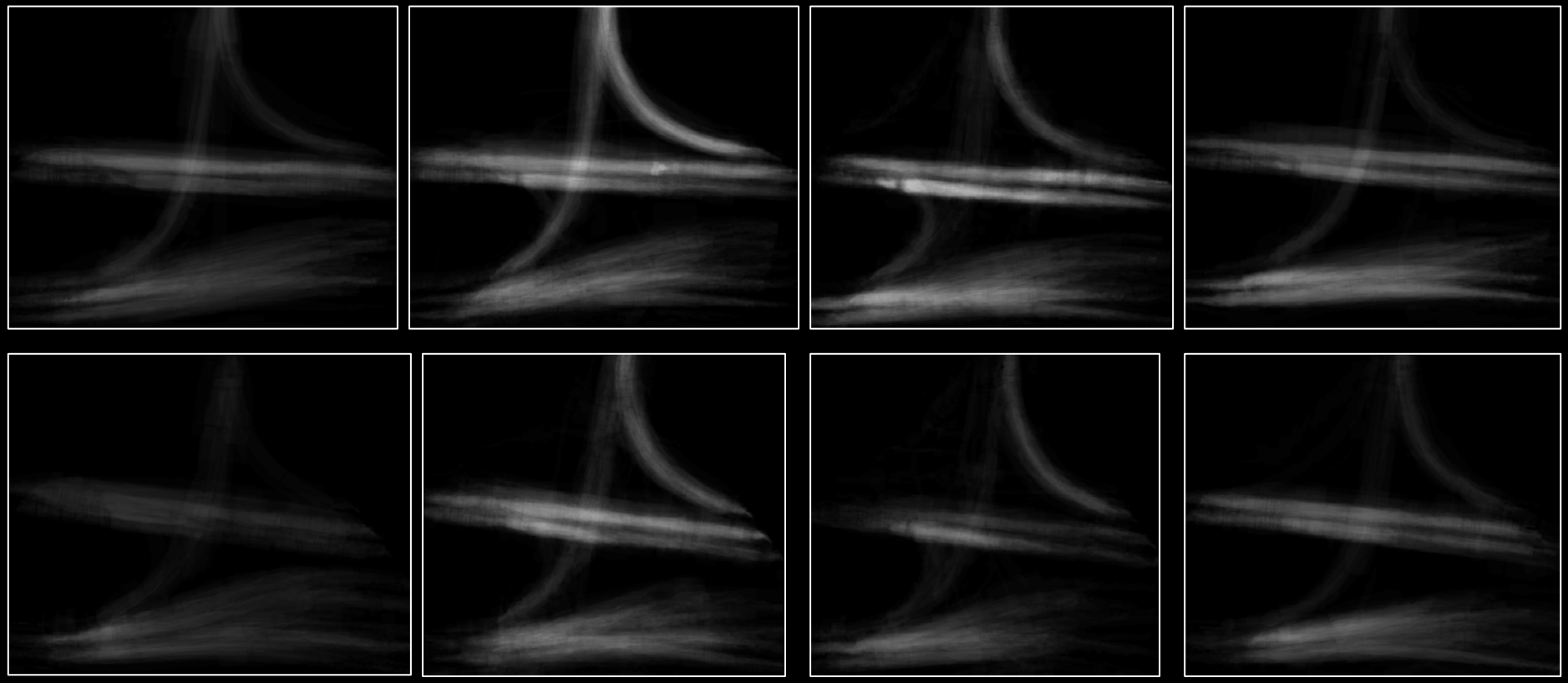
获取轨迹文件数目
（每10分钟一个文件）

7月16日：64

7月22日：31

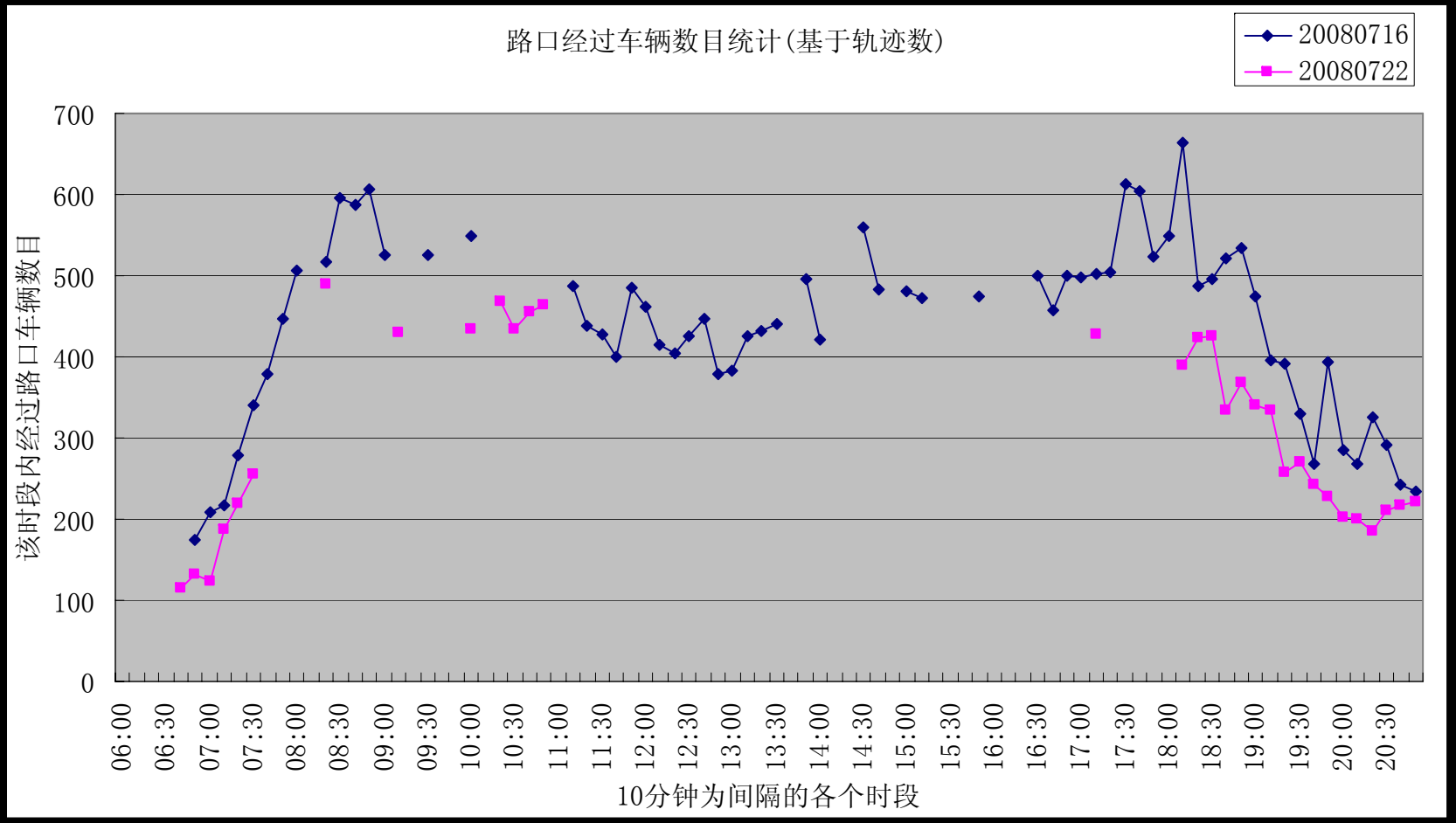
数据分析举例 - 车流密度

上：7月16日，下：7月22日



6:50 - 7:00　　8:20 - 8:30　　18:10 - 18:20　　20:40 - 20:50

车辆计数统计


路口经过车辆数目统计(基于轨迹数)
20080716
20080722
该时段内经过路口车辆数目
700
600
500
400
300
200
100
0
06:00
06:30
07:00
07:30
08:00
08:30
09:00
09:30
10:00
10:30
11:00
11:30
12:00
12:30
13:00
13:30
14:00
14:30
15:00
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30
10分钟为间隔的各个时段

Thank You!

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