

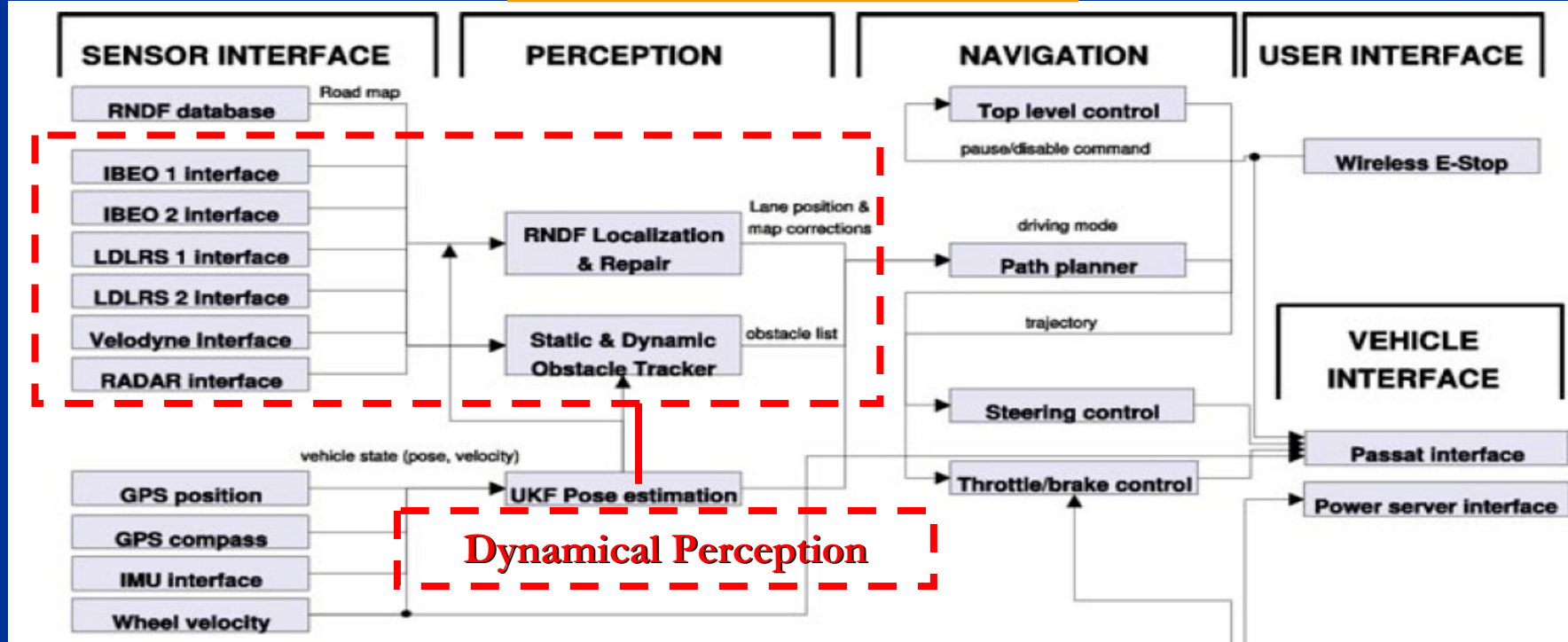
Dynamical Perception Modeling for Autonomous Driving

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1. Introduction

The Software Framework of Autonomous Vehicle



Inside the Our SmartV II

Velodyne HDL-64EZ (1个) SICK LMS291 (8个) GPS/IMU (1个) CCD (6个) 毫米波雷达 (1个) 热红外成像 (1个) PMD相机 (1个)



Chery Tiggo

车辆状态



Perception



Planning



Navigation



转向控制



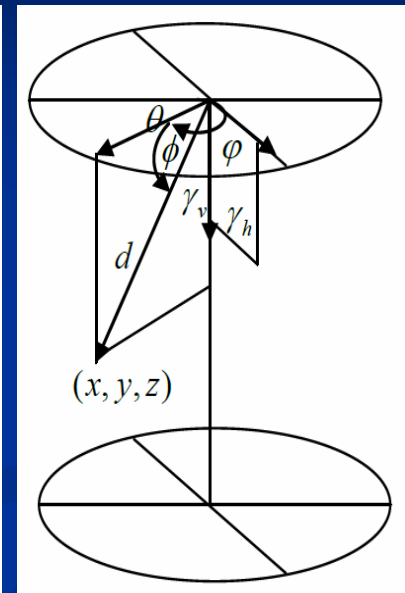
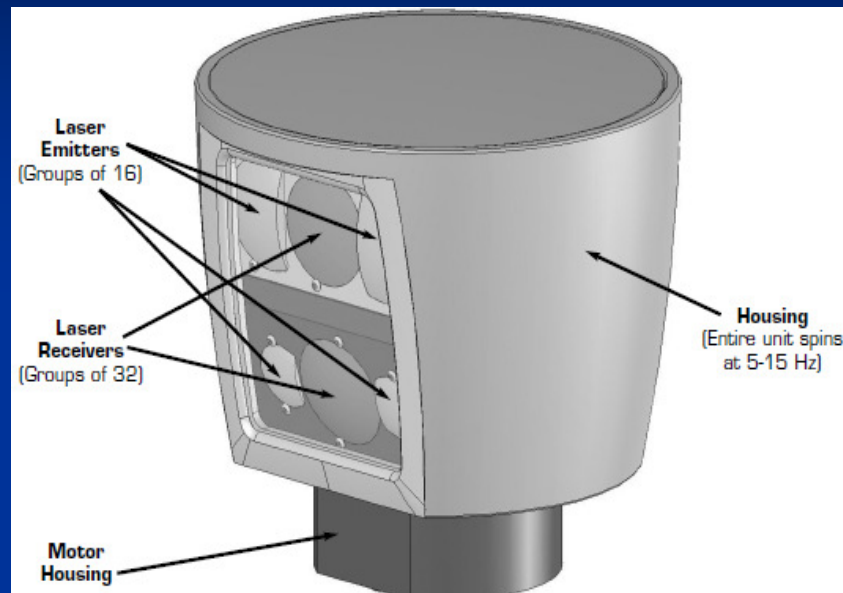
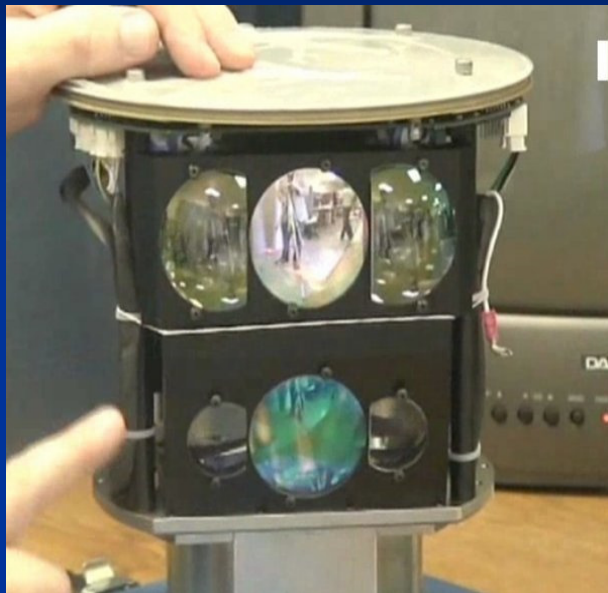
刹车控制



油门控制

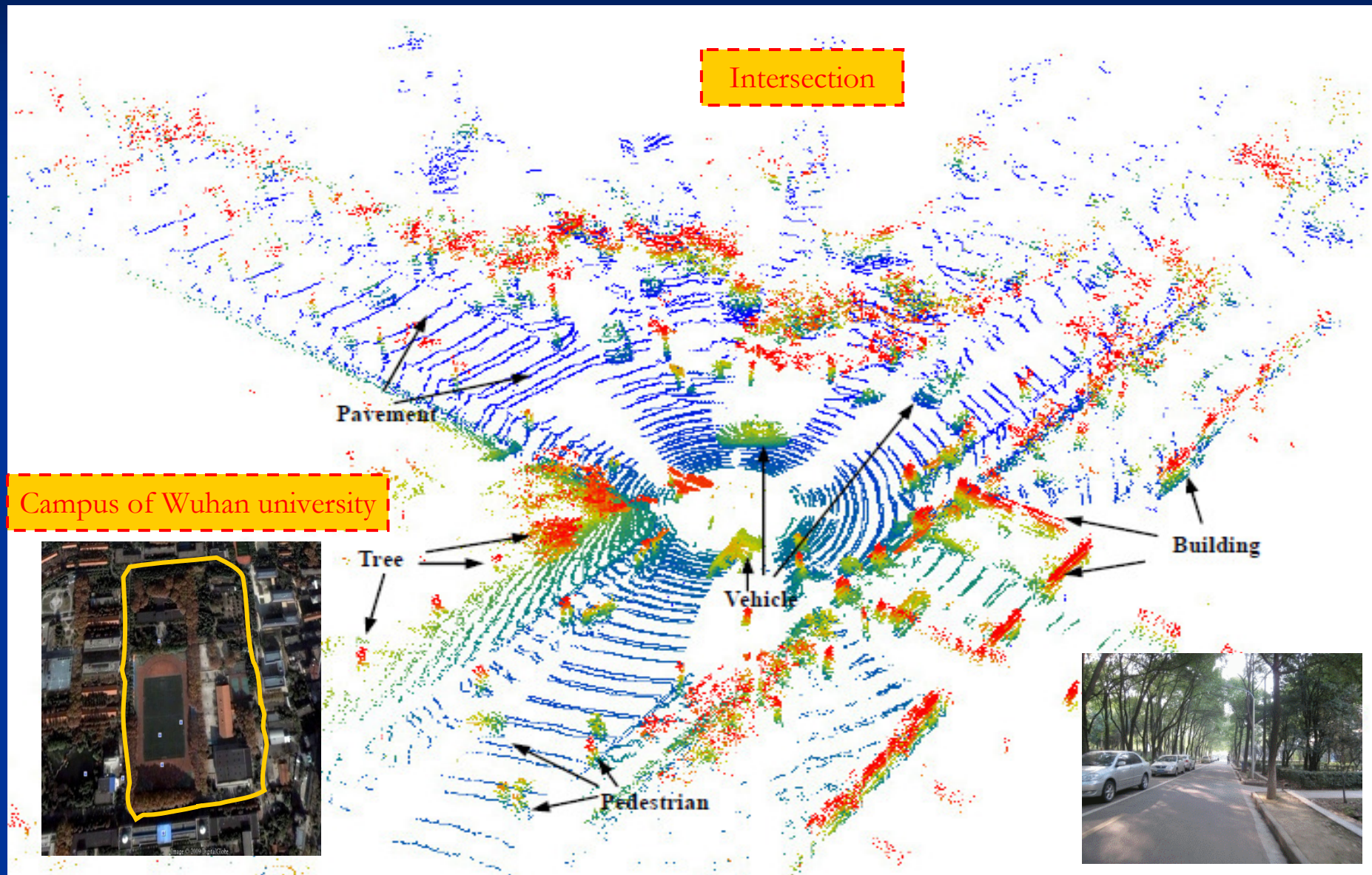
Control

Inside the Velodyne HDL- 64E



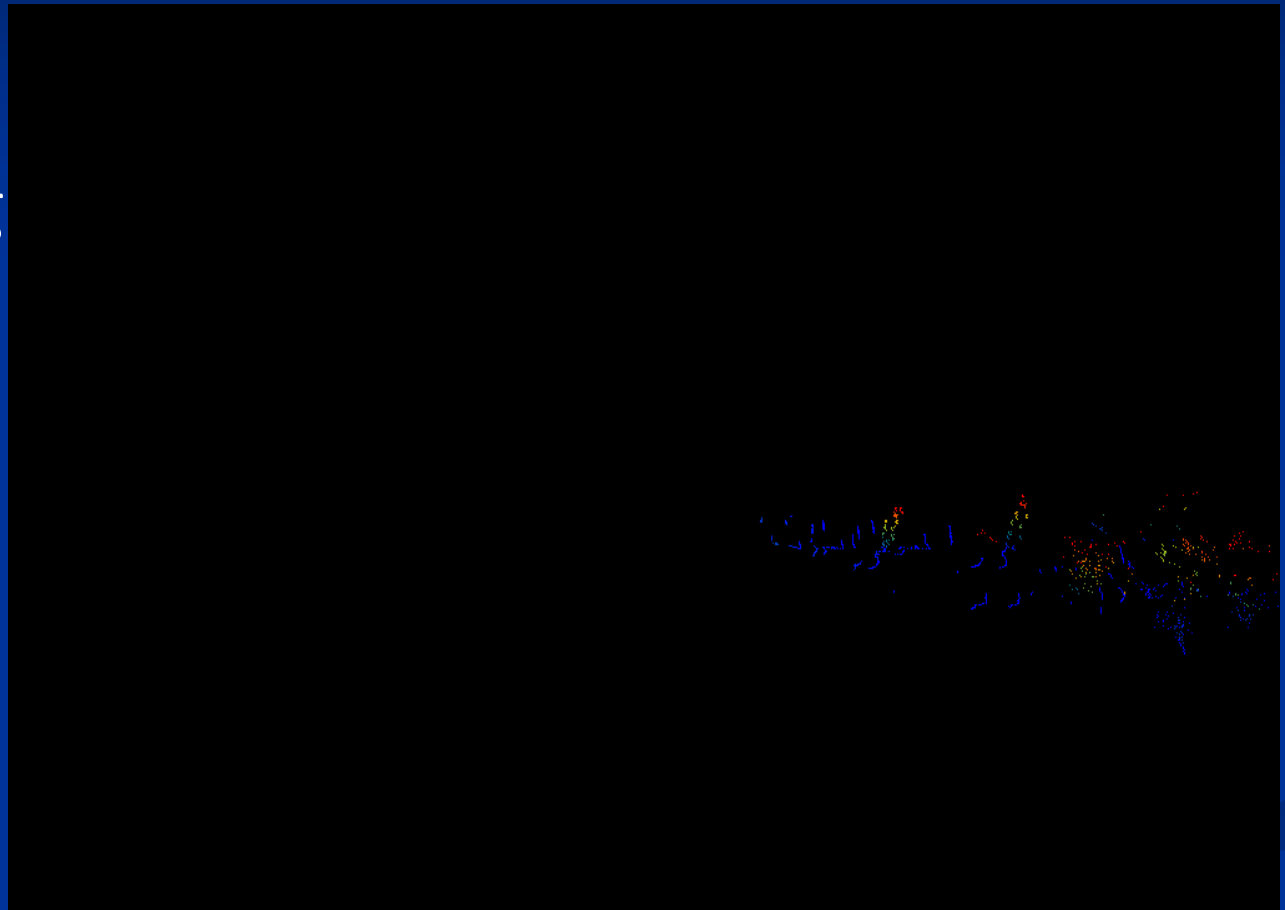
No	VertCorrection ($\Delta\phi$)	RotCorrection ($\Delta\theta$)	DistCorrection (Δr)	VertoffsetCorrection (γ_v)	HorizOffsetCorrection (γ_h)
1	-7.158120	-4.954240	0.000000	0.000000	-4.000000
2	-6.817820	-2.814700	0.000000	0.000000	4.000000
3	0.317822	2.814740	0.000000	0.000000	-4.000000
4	0.658119	4.954230	0.000000	0.000000	4.000000
5	-6.477650	-0.679162	0.000000	0.000000	-4.000000
6	-6.137590	1.455470	0.000000	0.000000	4.000000
...
64	-12.025314	1.018773	0.000000	0.000000	4.000000

Typical Driving Scene for Perception



The Slow Playback of Point Cloud

- Huge data
- 360° Scanning
- 64 Scan lines
- Irregular grid
- Dynamic



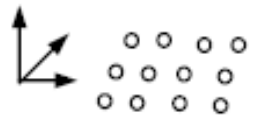
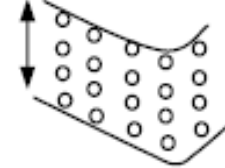
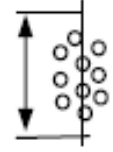

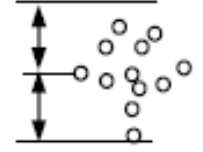
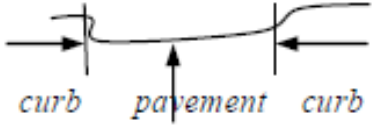

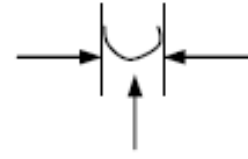







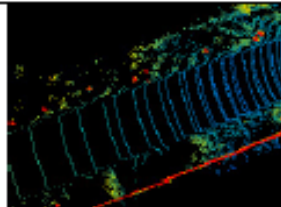
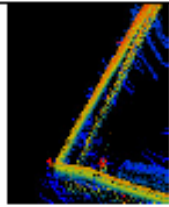
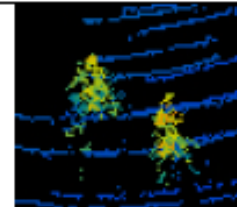
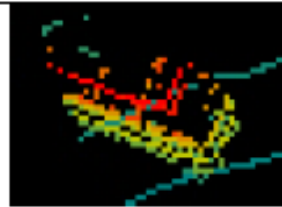
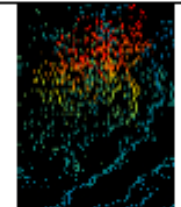
The slow playback show whole scan process, and dynamic run !

2. Features Selection

Feature Selection

- By removing most irrelevant and redundant features from the data, feature selection helps improve the performance of learning models by:
 - Enhancing generalization capability.
 - Speeding up learning process.
 - Improving model interpretability.

The Feature Model

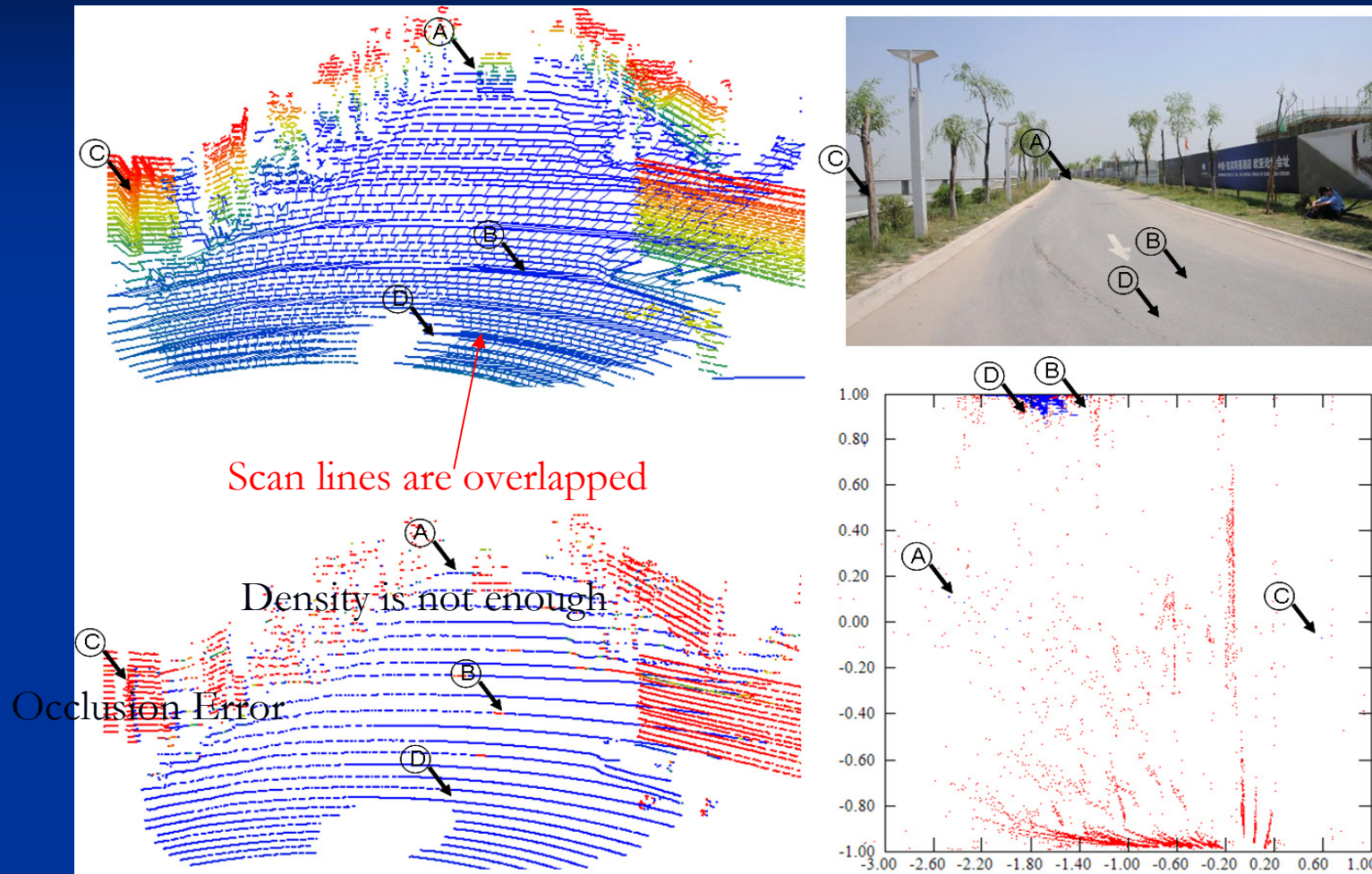
Type		Road	Building	Pedestrian	Vehicle	Trees
theory model	Points					
	Line					
	Surface					
Real scenes	data					

The 3D Features Definition

Type	Feature	Formula	Scale	Representation
Points	Height(z)	$z = z_{i,j}$ (1)	Every points	The height of each point of one object
	Average of height(\bar{z})	$\bar{z} = \frac{1}{16}(\sum_{i,j} z_{i,j})$ (2)	4×4 points	The height of local plane
	Difference in height(Δz)	$\Delta z = \frac{1}{16}(\sum_{i,j} z_{i,j} - \bar{z})$ (3)	4×4 points	The surface point of fluctuation
Line	Length of segment (Δl)	$\Delta l = \sqrt{(l_s - l_e)^2}$ (4)	8~32 points	The size of the scanline on object
	Segment curvature(Δk)	$k = \frac{d\varphi}{ds} = \frac{y''}{(1+y'^2)^{\frac{3}{2}}}$ (5)	8~16 points	The change in surface curvature
Surface	Normal vector(\vec{n})	$\vec{n} = \overrightarrow{M_1 M_2} \times \overrightarrow{M_1 M_3}$ (6)	Between two scanlines	The local plane
	The angle between normal vector and the Z axis(ρ)	$\rho = \frac{\pi}{2} - \langle \vec{n}, \vec{z} \rangle = \frac{\pi}{2} - \arccos \frac{\vec{n} \cdot \vec{z}}{ \vec{n} \cdot \vec{z} }$ (7)	Between two scanlines, 4~16 in one scan line	Surface orientation
	The included angle of two adjacent surfaces(β)	$\beta = \langle \vec{m}, \vec{n} \rangle = \arccos \frac{\vec{m} \cdot \vec{n}}{ \vec{m} \cdot \vec{n} }$ (8)	Between two scanlines, 4~16 in one scan line	Local Convexity

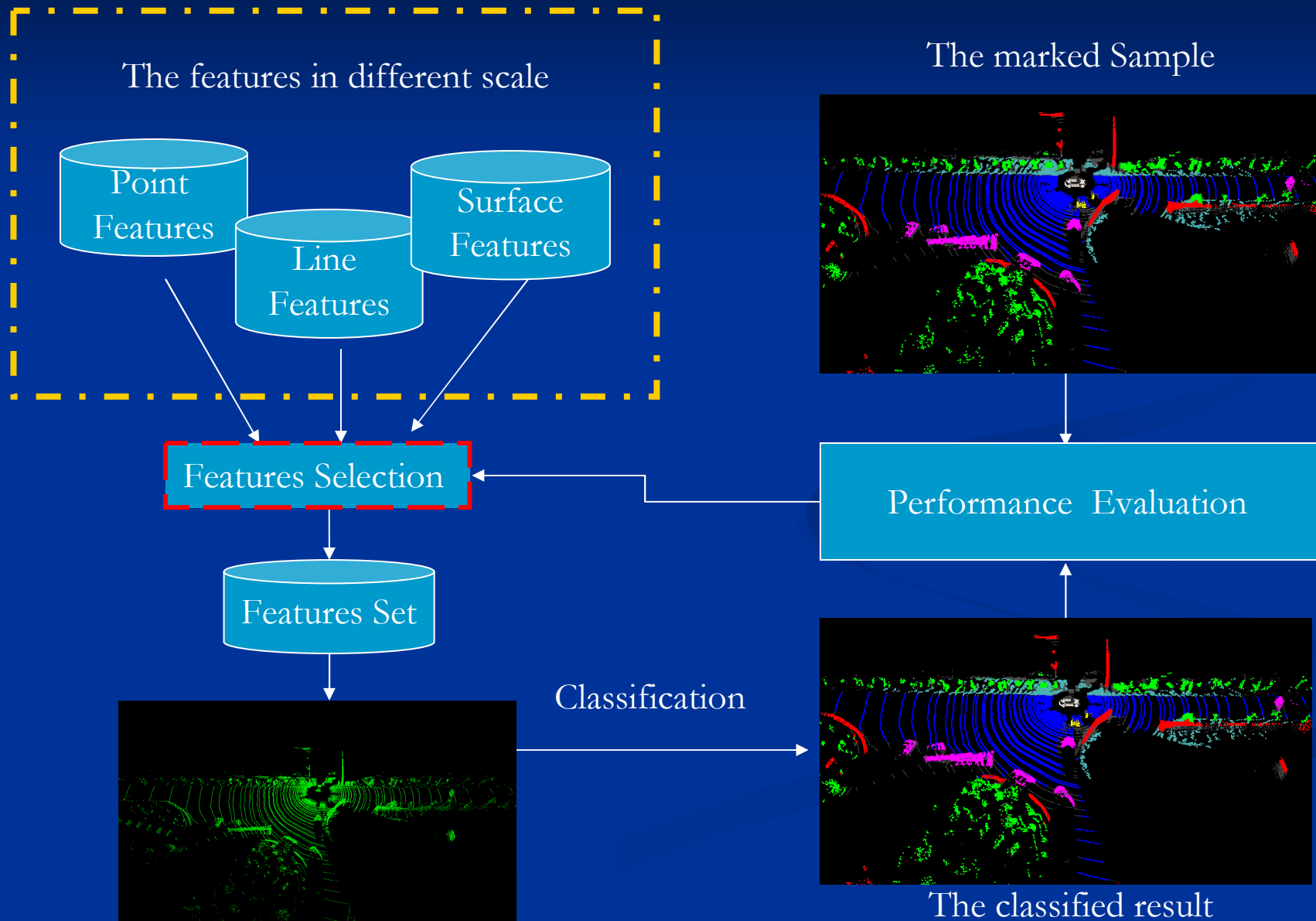
There can be optimized the feature extraction parameters such as scale.

The Distribution of Normal Vector



Therefore, It is necessary to perform further processing, such as feature selection, to improve the classification robustness

Features Selection



3. Demo. 1: Road Detection

The Challenge of Road Perception (1)



In order to distinguish road and ground, it's structure must be considered

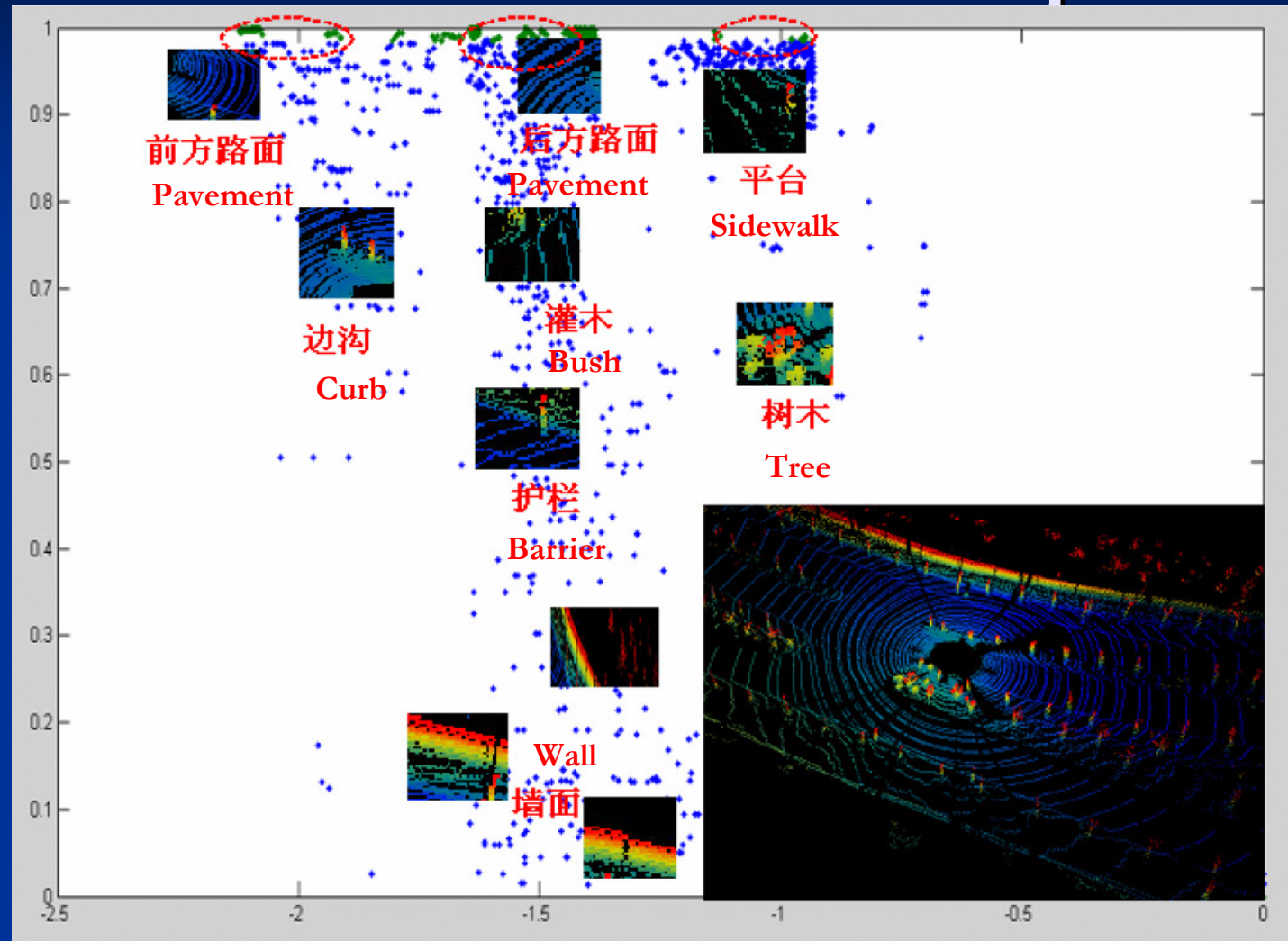
The Challenge of Road Perception(2)



Moreover as sensors is mounted on moving vehicles,
Road detection must adapt to shake of moving!

The Distribution of feature Space

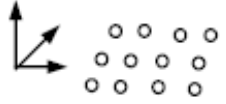
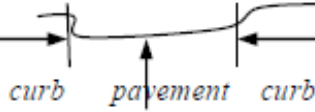
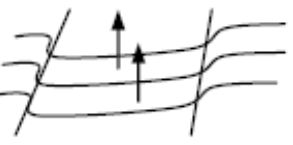
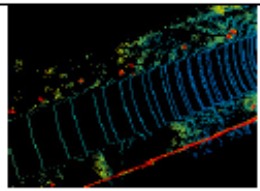
The Angle
between
normal vector
and Z axis

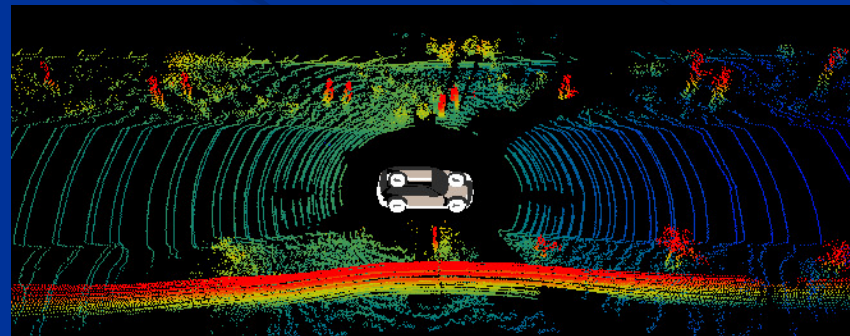
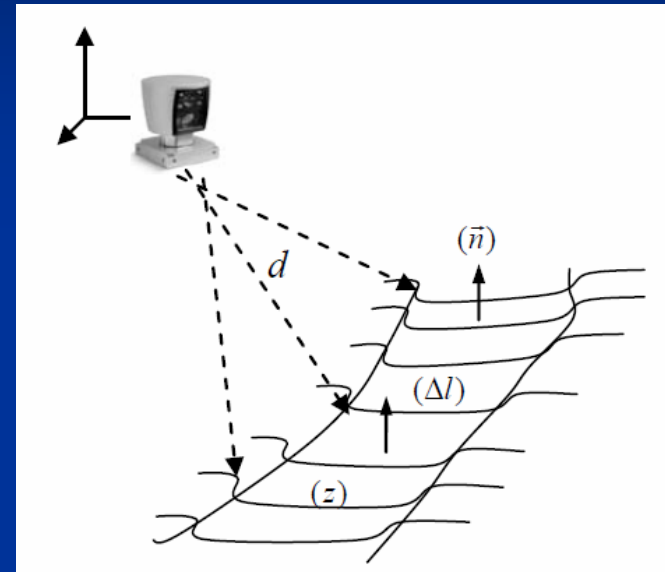


The height of point cloud

It can't distinguish pavement and sidewalk only using normal vector!

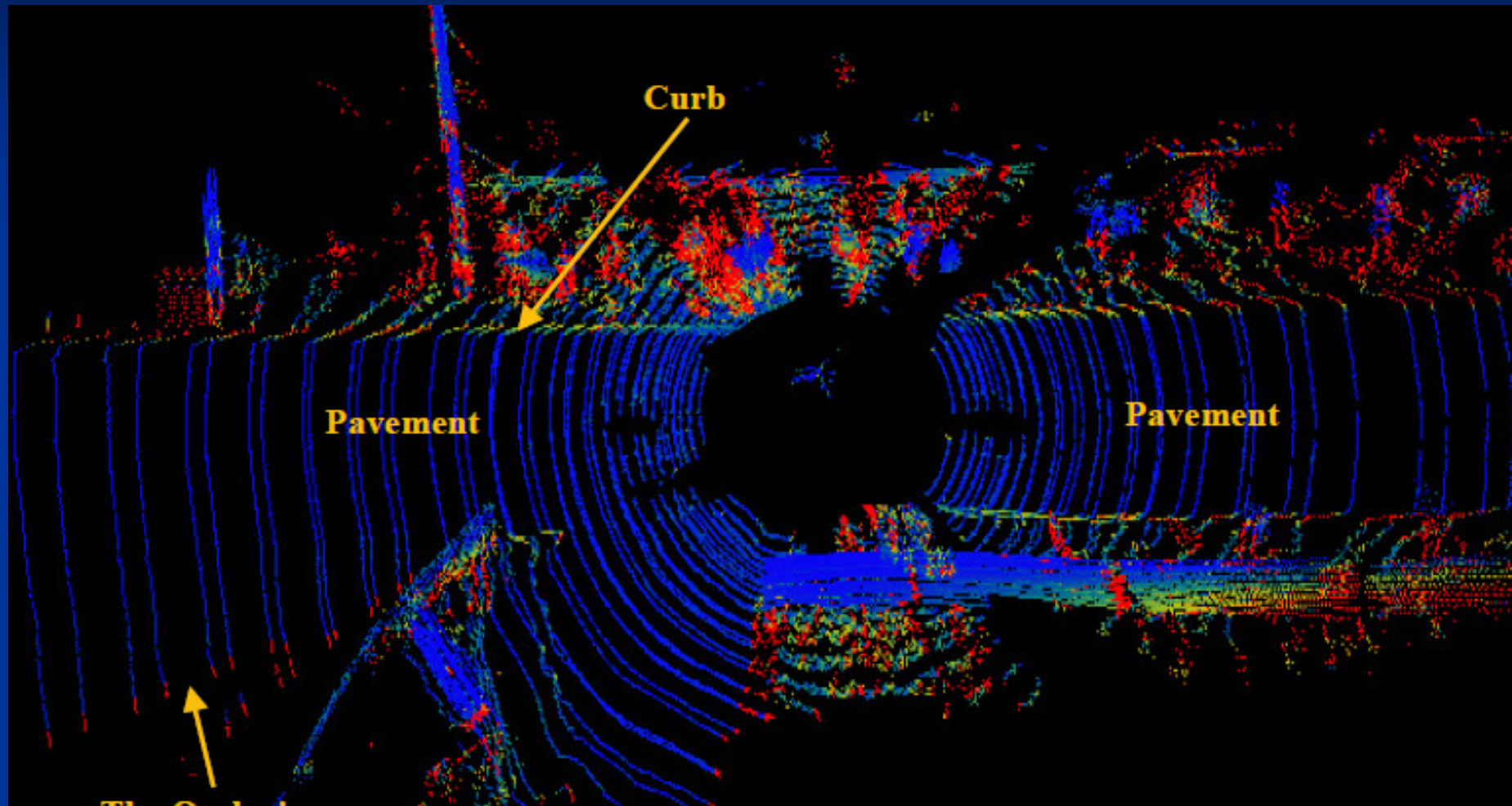
The Road in point, line and surface

Type		Road
theory model	Points	
	Line	
	Surface	
Real scenes	data	



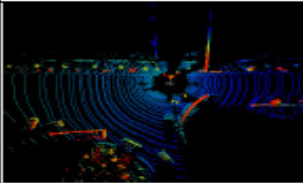
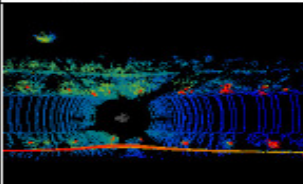
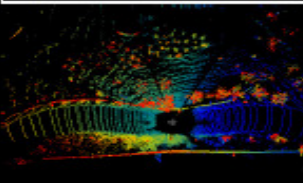
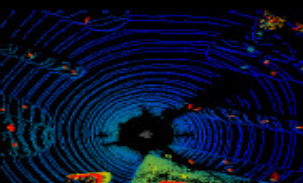
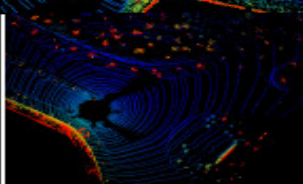
The road consists of three parts; both sides are curbs and the pavement in the middle of it.

The Merit of Scan line Feature



Because the structure is fixed, even in a small vibration cycle,
The feature is stable while the carrier is shaking !

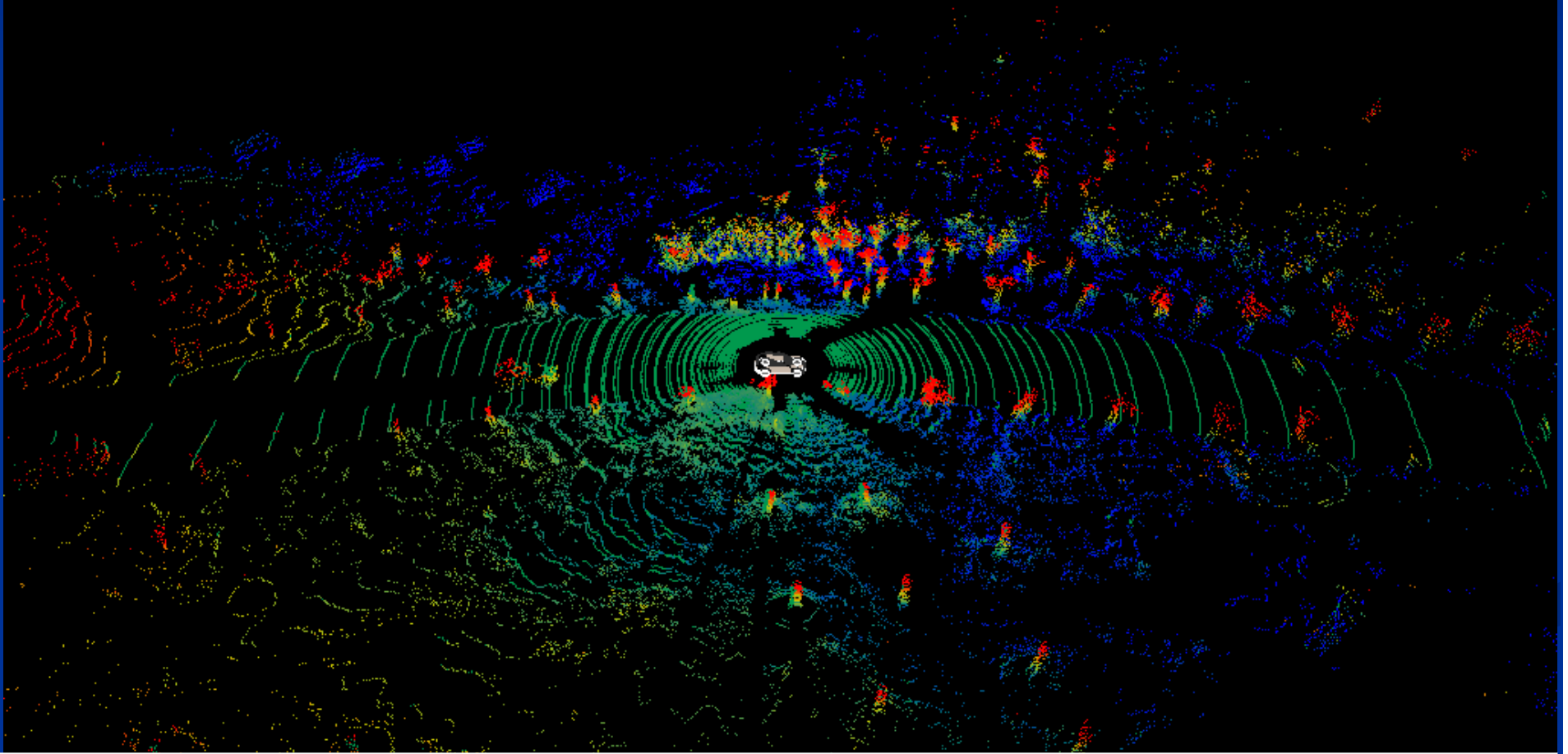
The Road Classification Results

<i>Sequecne.</i>	<i>Frame</i>	<i>Position</i>	<i>Reference image</i>	<i>Class</i>	Algorithm of Universit at Karlsruhe	
					<i>Local Convexity</i>	<i>3D Feature</i>
<i>FC09</i>	<i>2</i>	<i>The Origin</i>		<i>Decision Tree</i>	99	100
				<i>Bayes</i>	89	91
				<i>KNN3</i>	99	100
	<i>302</i>	<i>The Straights</i>		<i>Decision Tree</i>	91	96
				<i>Bayes</i>	82	90
				<i>KNN3</i>	90	95
	<i>802</i>	<i>The Curve</i>		<i>Decision Tree</i>	73	78
				<i>Bayes</i>	77	82
				<i>KNN3</i>	74	78
	<i>1102</i>	<i>The Intersection</i>		<i>Decision tree</i>	82	90
				<i>Bayes</i>	88	91
				<i>KNN3</i>	84	88
	<i>1602</i>	<i>The U-Turn</i>		<i>Decision tree</i>	79	87
				<i>Bayes</i>	82	82
				<i>KNN3</i>	81	86

Our algorithm

The Road Detection Demo

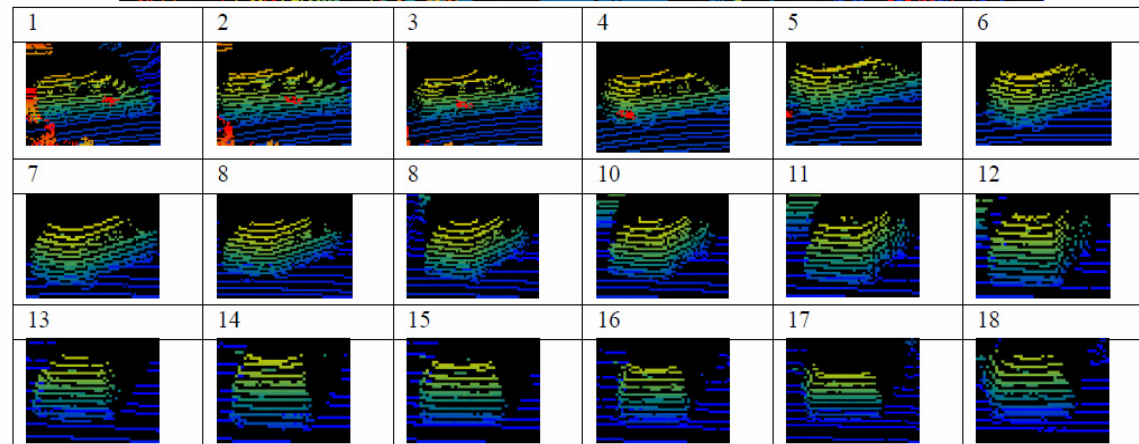
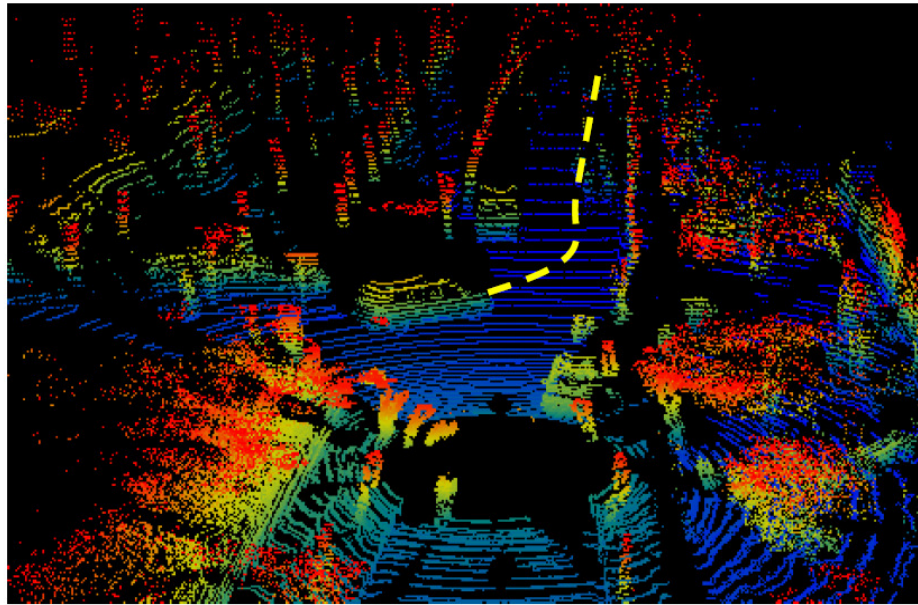
Runing in rugged road of Xi'An public park, and there are lots of noise in point cloud.



The road extraction is very complete and the boundaries is clear

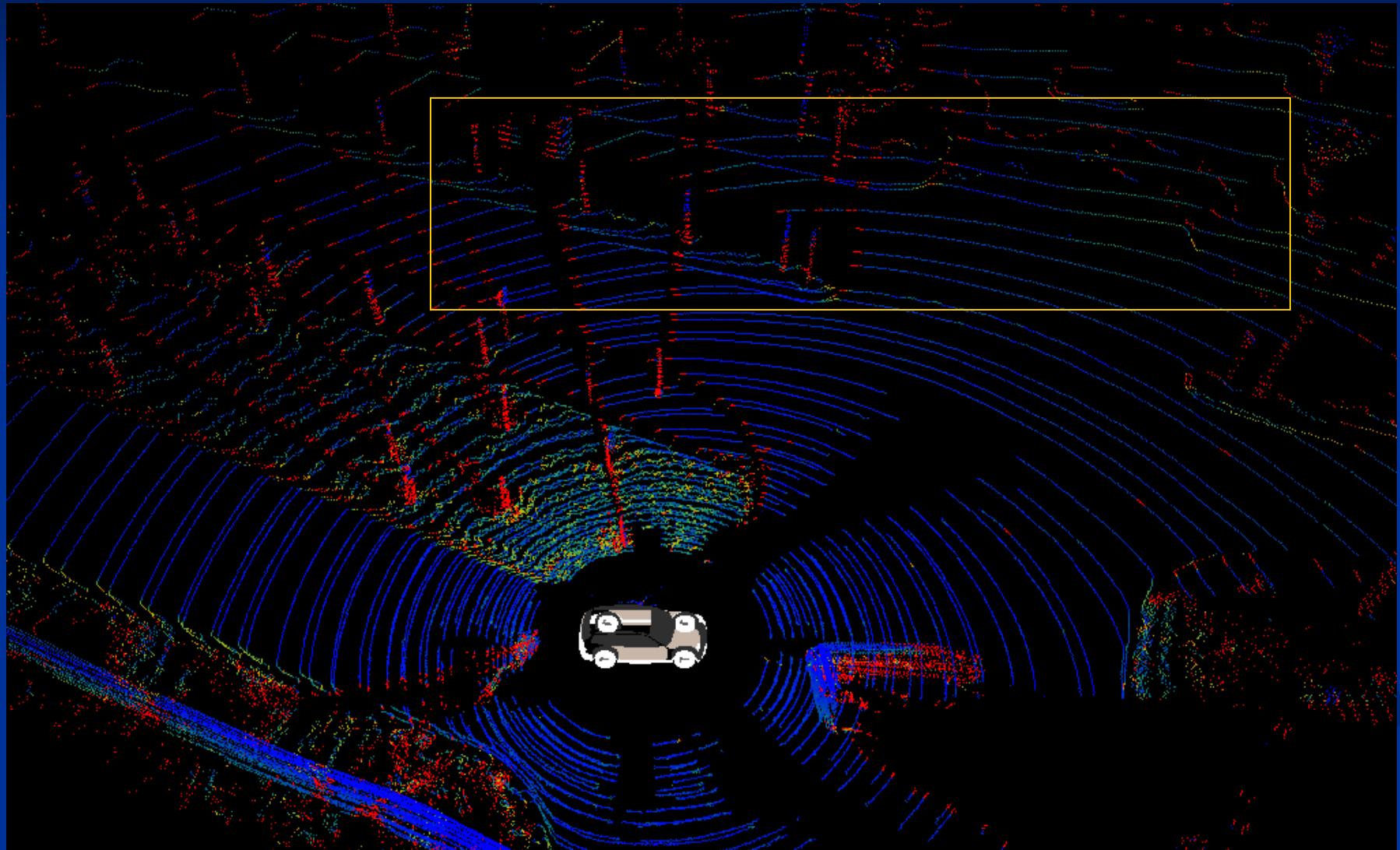
4. Demo. 2: Vehicle Detection

The Challenge for Vehicle Detection(1)



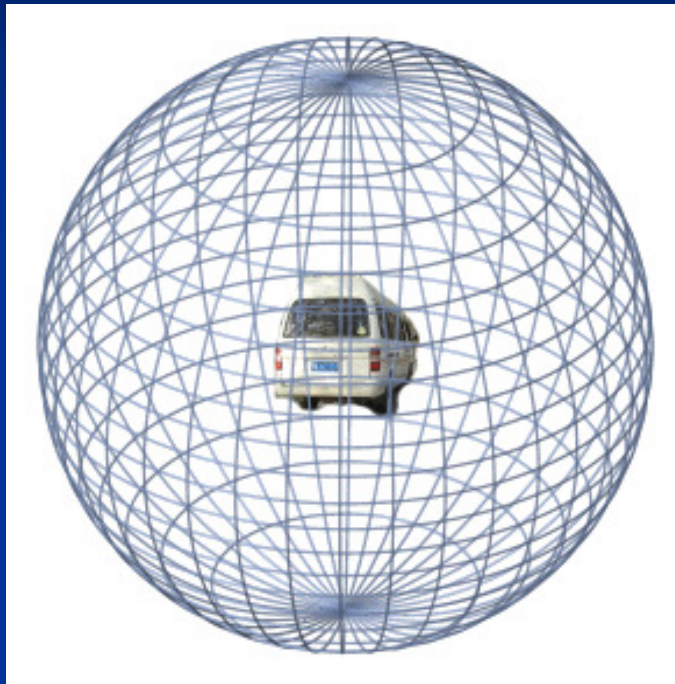
As the vehicle moving farther, its outline is changed,
and the density of point cloud will decrease

The Challenge for Vehicle Detection(2)





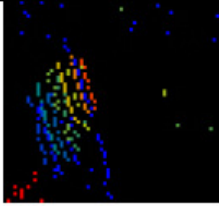
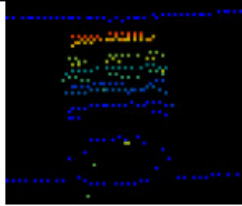
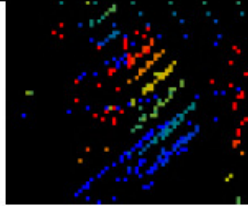
It must handling noise of other object occlusion!

The Observe Model for Detection



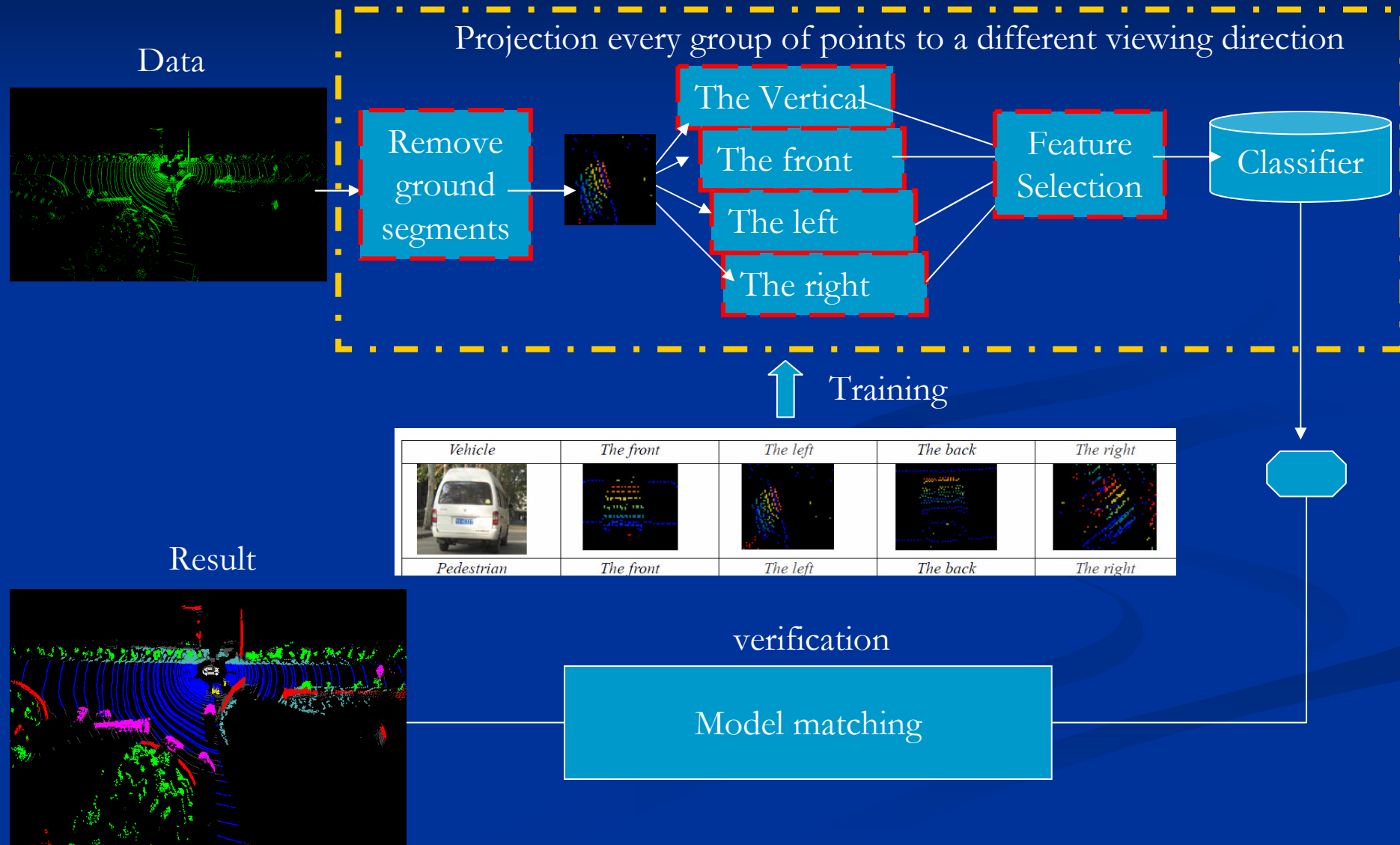
Statistics the feature distribution of vehicles in different observe directions

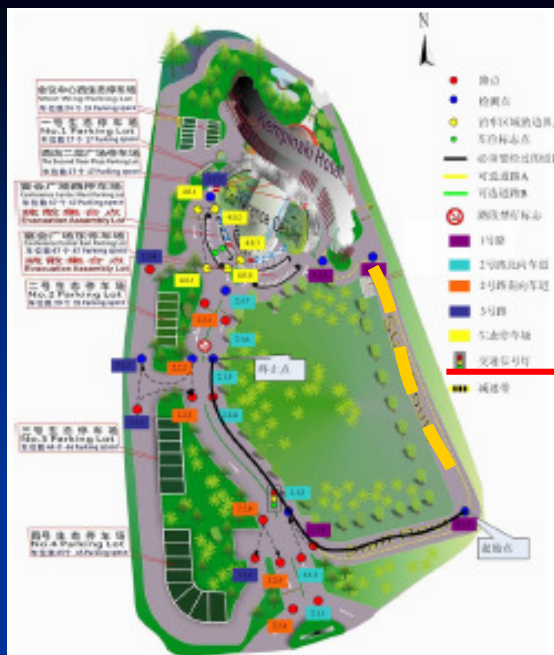
Combine them and Remove redundancy, to improve recognition performance .

<i>Vehicle</i>	<i>The front</i>	<i>The left</i>	<i>The back</i>	<i>The right</i>
				

The Different models were represented for different aspects of the vehicle in classification!

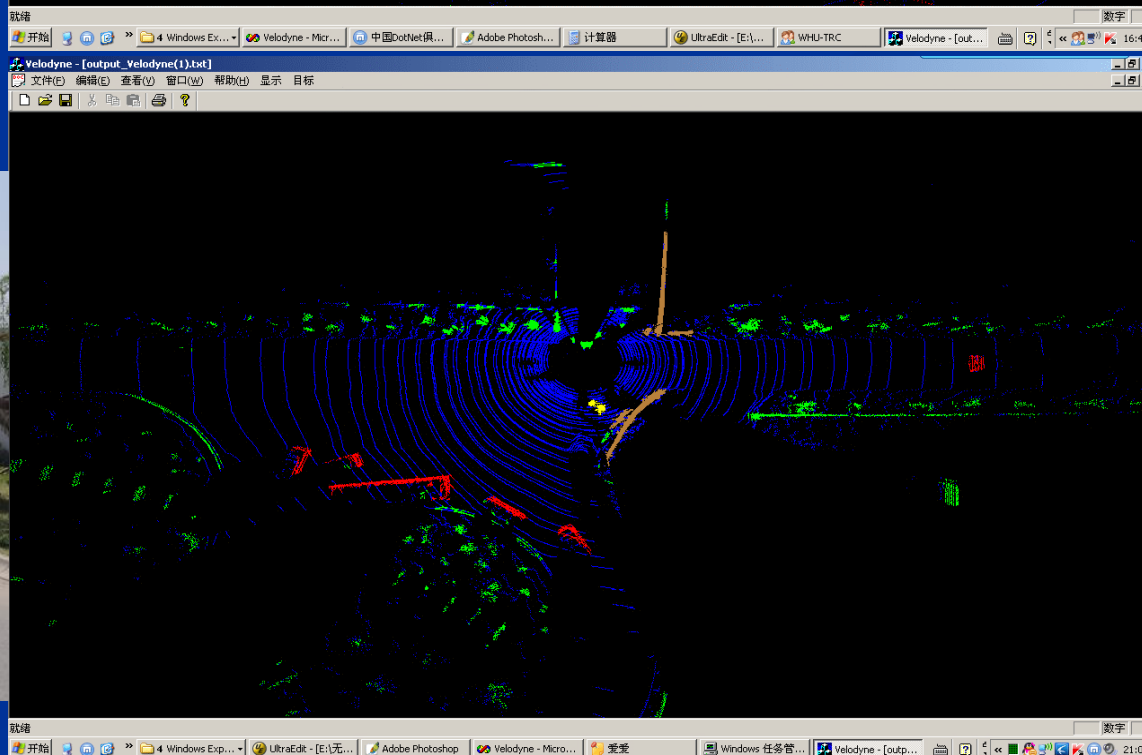
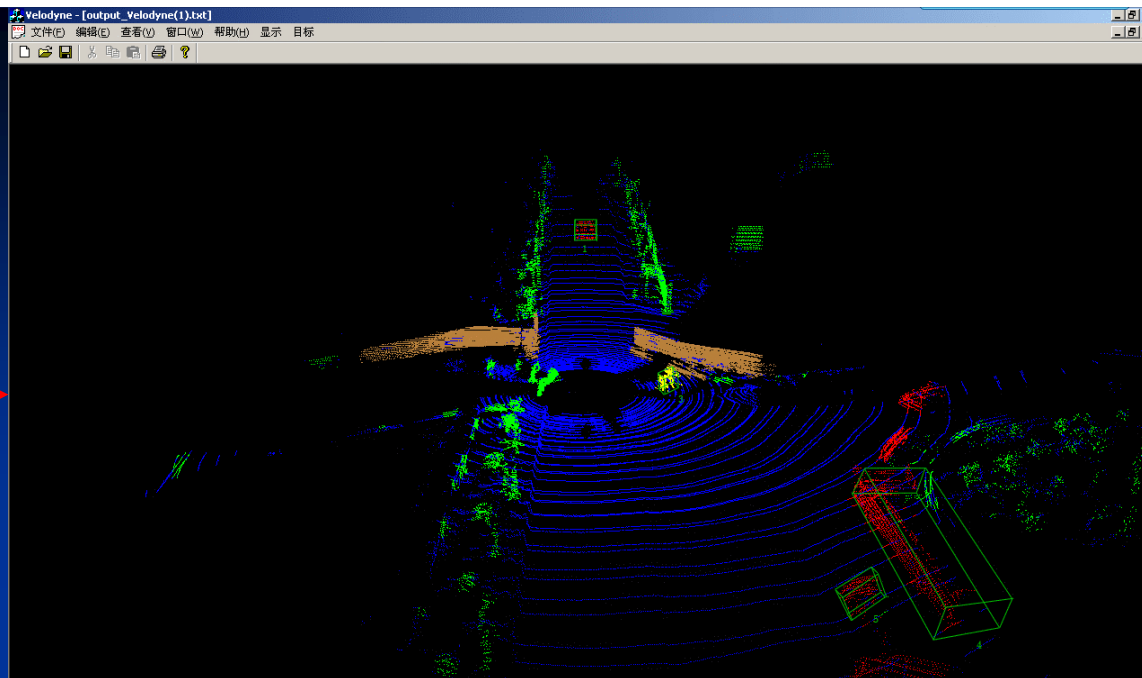
Multi-Models Classification





Map of Future Challenge 09

The vehicles have different posture.



5. Conclusion

The Conclusion

- First , as the perception of driving environment is a dynamic process, the sample space can not cover all the situation . In order to detection road robust, it must be analyzed model of road and selection stable feature to classify.
- Second, the occlusion is big problem and the object can usually detect only one aspect by lidar, Therefore, the projection a clusters of point cloud to a different viewing direction is good method for detection vehicle.

Thanks !