ZENRIN
Maps to the Future

Highly Efficient HD Map Creation: Accelerating Mapping Process with GPUs

May 10, 2017

ZENRIN Co.,Ltd.

Maps to the Future

Have you ever travelled to Tokyo?

ZENRIN
Maps to the Future

How did you get to your destination?

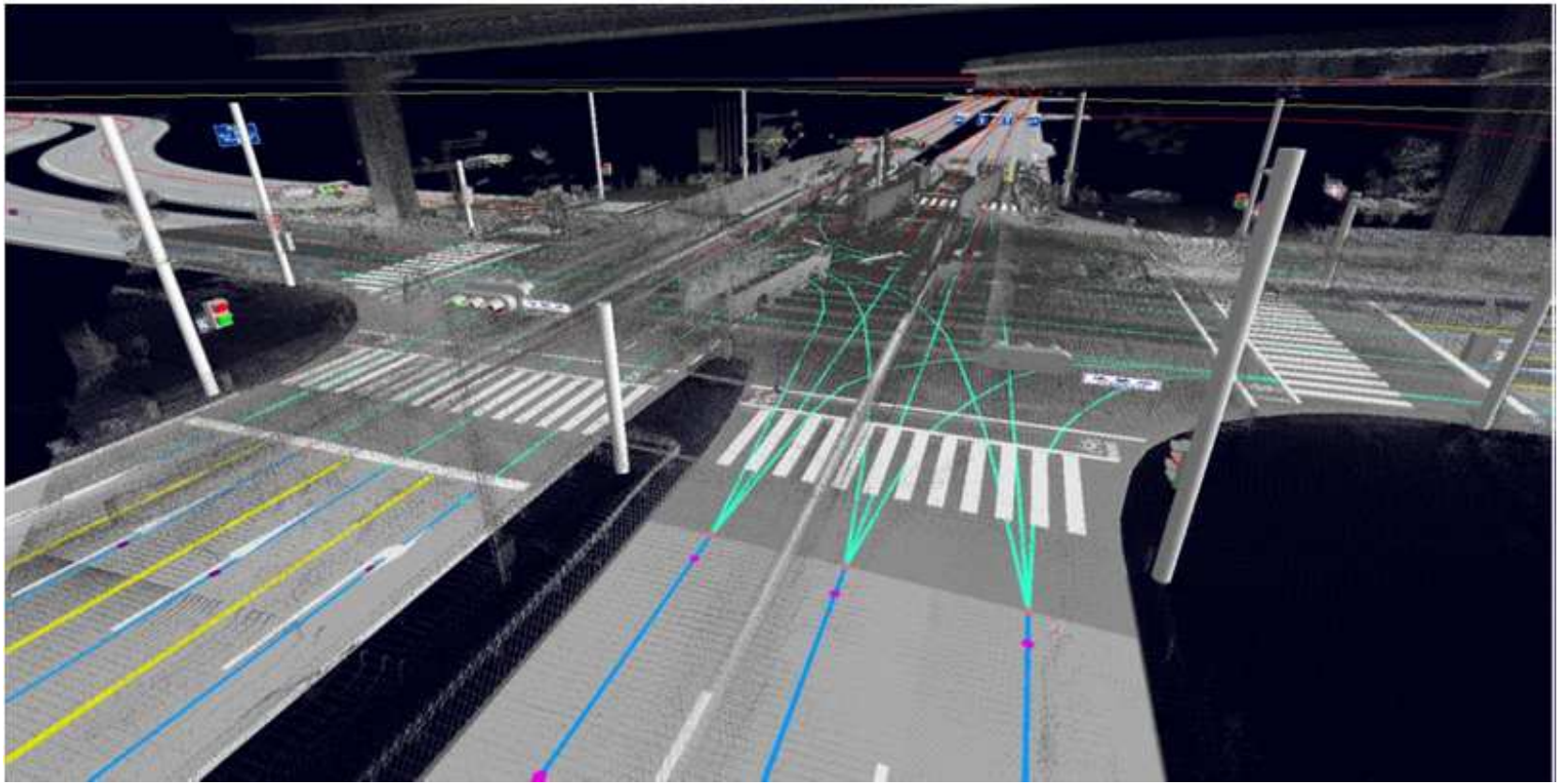
ZENRIN History

- **Founded in 1948 in Beppu, Oita Prefecture of Japan as a publisher of tourist maps**
- **Over 60 years in the mapping arena**
- **Maps covering 100% of Japan residential areas**

What's an HD map?

HD (High Definition) Map

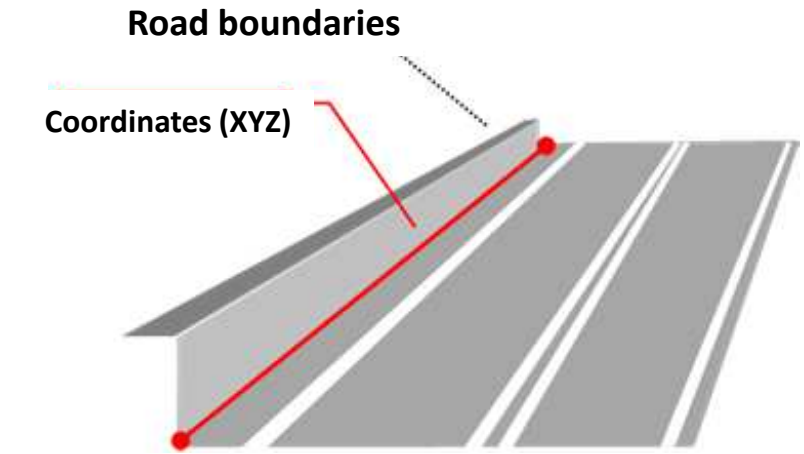
ZENRIN
Maps to the Future

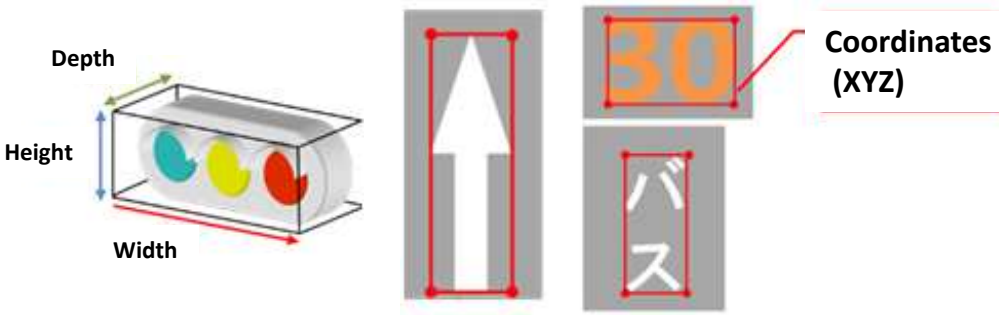


Highly detailed and precise 3D map for autonomous driving

3D Geometry

- ✓ Lane marks, road boundaries, traffic signs, signals etc.
- ✓ Polylines or polygons
- ✓ Latitude, longitude, altitude
- ✓ Height, width, depth
- ✓ Sub-meter accuracy to WGS84
  - Car-navigation 10 meter





How it is used in autonomous driving?

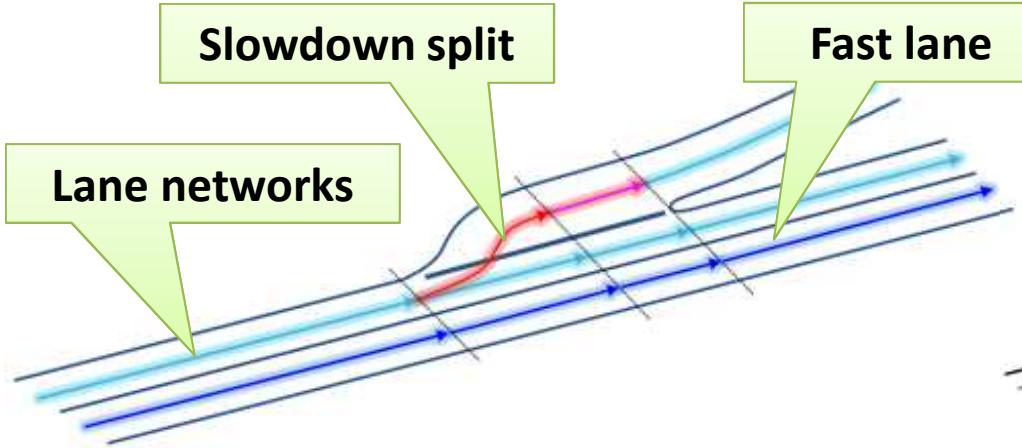
More precise localization in various conditions (e.g. inside tunnels) than GPS only

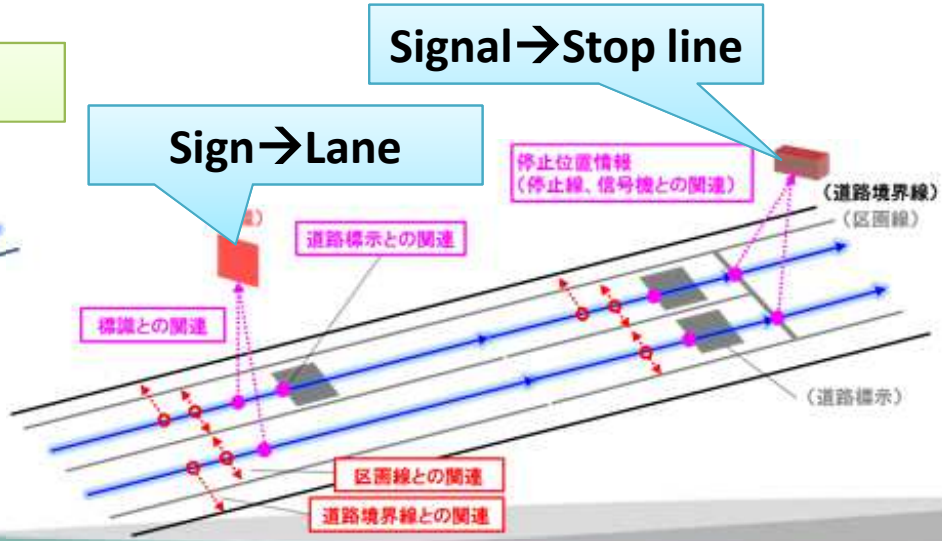
- With the given camera parameters, project map elements to the camera view
- Calculate the accurate camera (car) position and orientation assuming that the map is correct

Semantic Information

ZENRIN
Maps to the Future

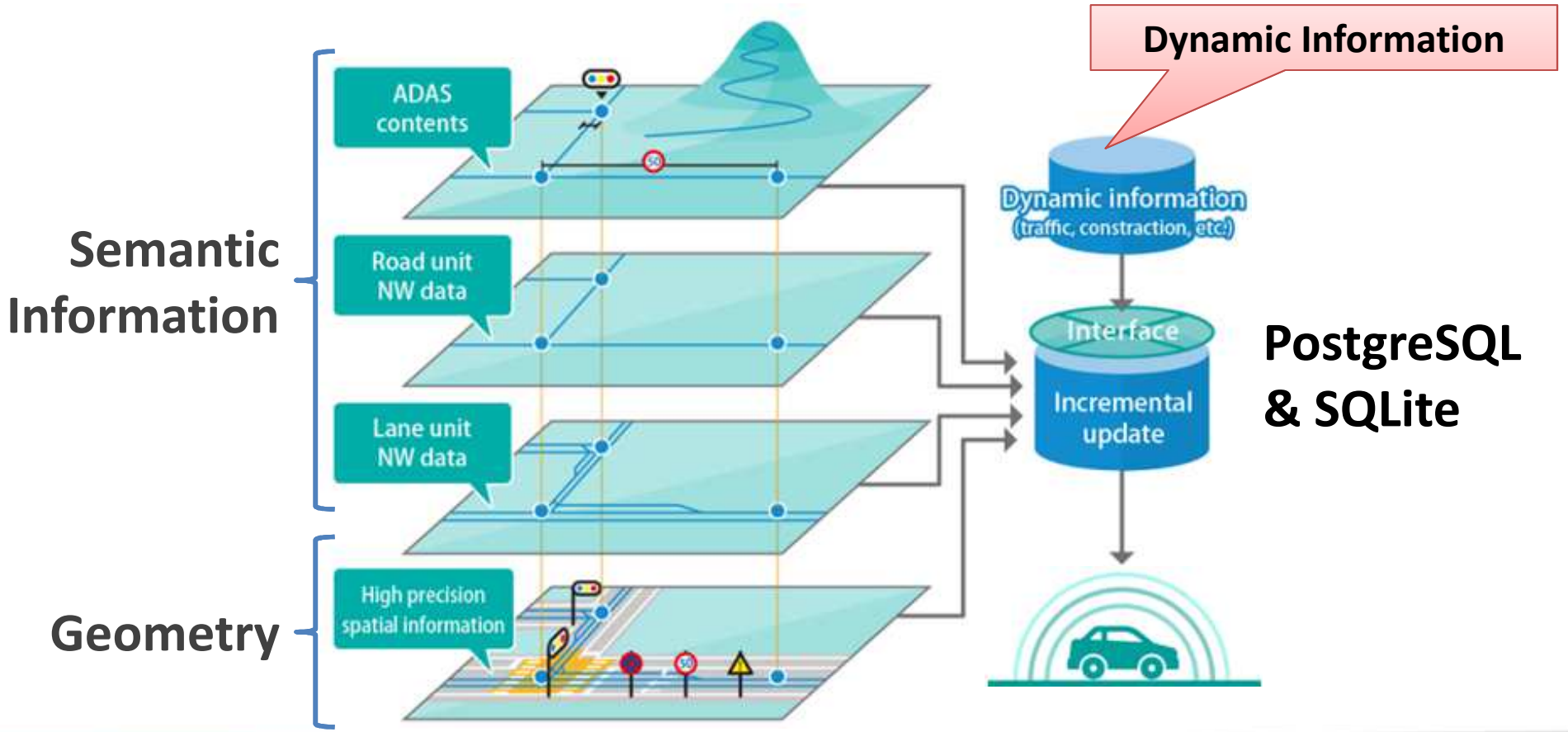
- ✓ Meaning of the road scene
- ✓ Traffic rules, road element associations, etc.
- →Autonomous Driving: Lane level navigation, safe & efficient path planning





Data format: ZENRIN Geospatial data Model (ZGM)

ZENRIN
Maps to the Future



How to create an HD Map?

Typical HD mapping process

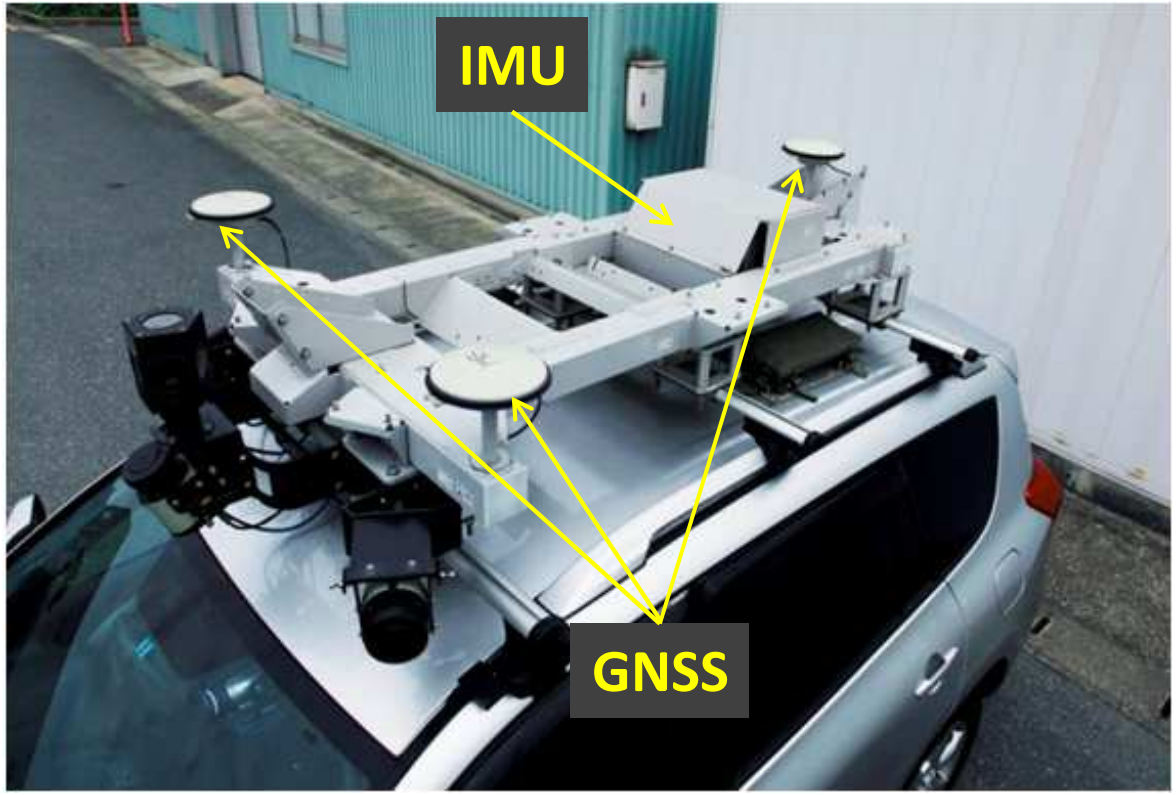
ZENRIN
Maps to the Future

1. Data collection

2. Data processing

3. Verification

Step 1. Data collection → Survey vehicle



Massive volume of data!

ZENRIN
Maps to the Future

→Maximum Approx. 1TB of data per car per day

High Resolution 2D Image
>30M pixel

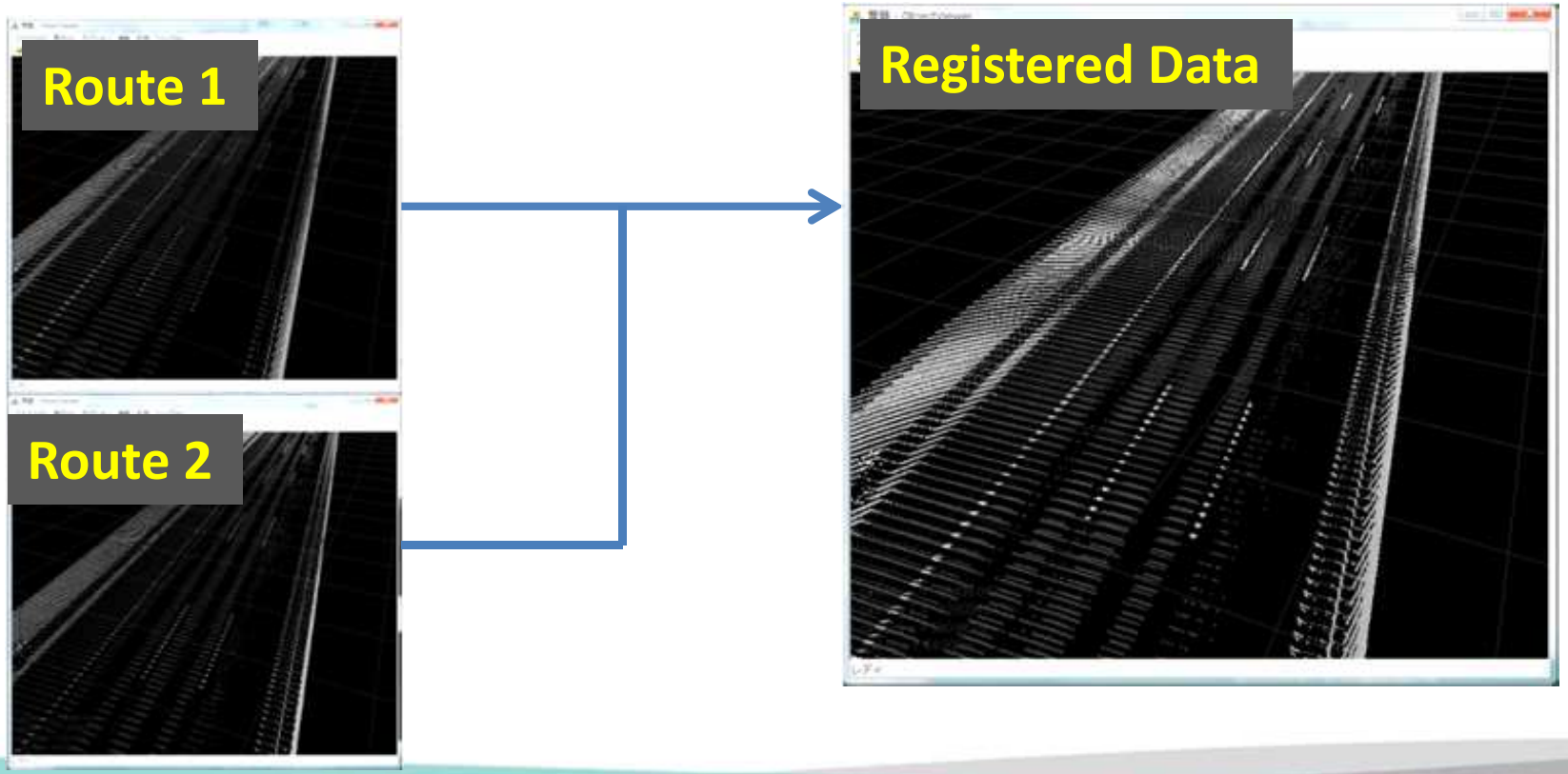
Dense Point Cloud Data
>700,000 points/sec

Other Sensor Data

Point cloud data registration

ZENRIN
Maps to the Future

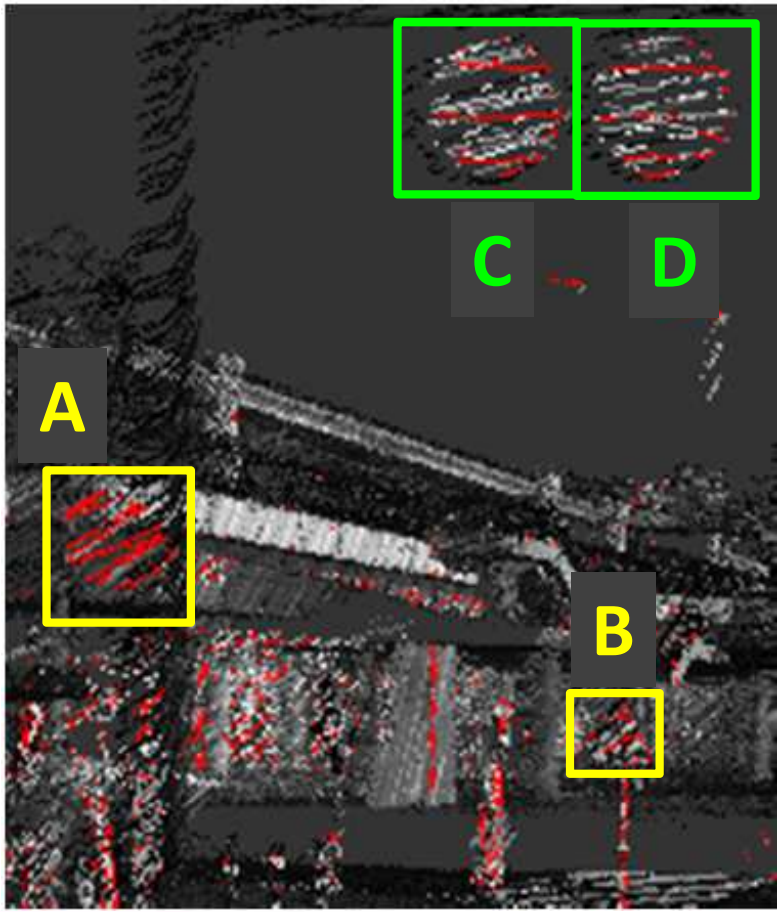
- **Connecting data to create a 3D model of a certain area**

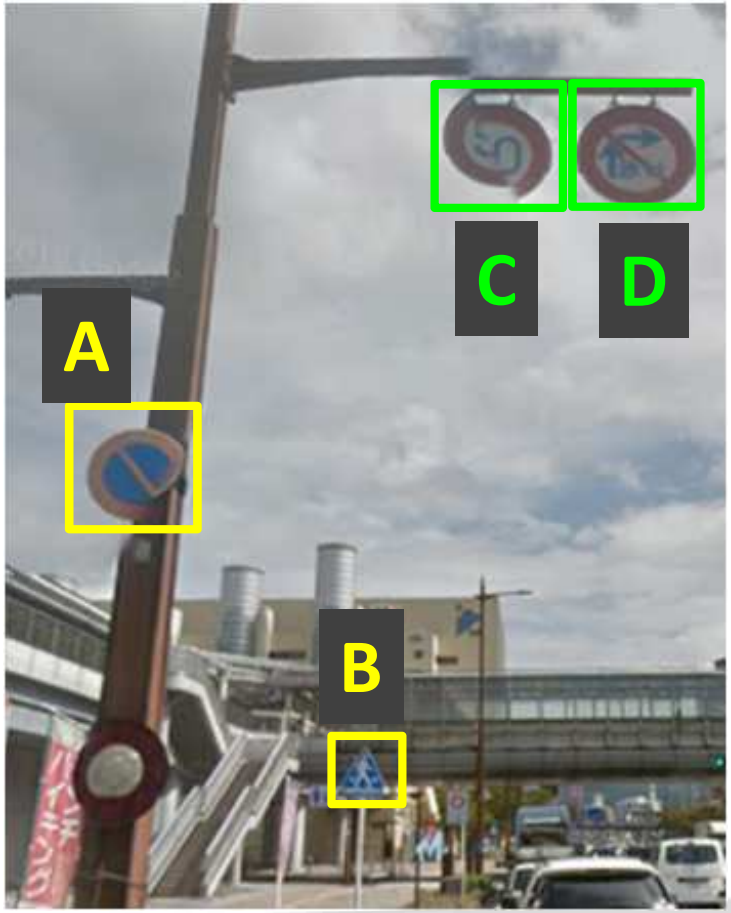


Finding objects from the point cloud data

ZENRIN
Maps to the Future

Verifying and understanding signs with 2D images





* Photo from Google Street View

Mapping & Step 3: Verification

ZENRIN
Maps to the Future

- ✓ Primitive geometry extraction
- ✓ Annotation
- ✓ Quality assurance
- →In-house software tools

Mapping Japan is an extraordinary task…

Road Length: 1,218,772 km

Traffic Signals: 207,000 units

Traffic Signs : 9,790,000 units

Ref. WHITE PAPER ON TRAFFIC SAFETY IN JAPAN 2016, Cabinet Office

HD mapping challenges

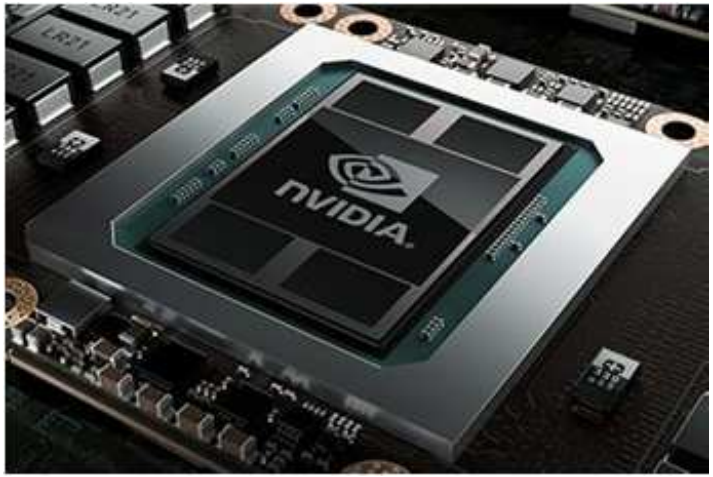
ZENRIN
Maps to the Future

- ✓ **Massive volume data processing**
- ✓ **Huge computing resource & time**
- ✓ **Skilled operators. Lot's of operators…**
- ✓ **Keep updating the map**

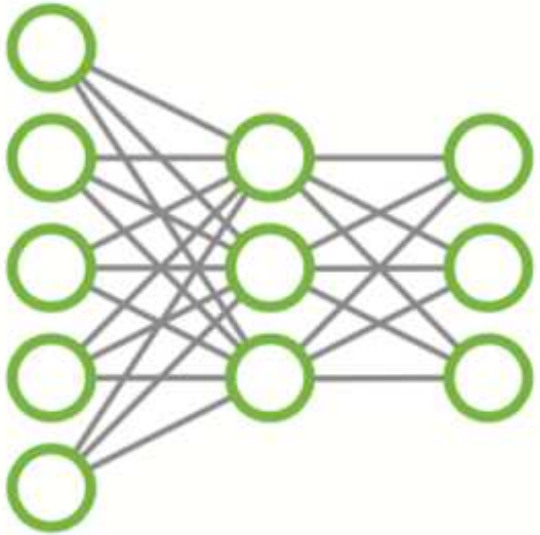
Accelerating the mapping process

How?

GPU



AI (DNN)



*DNN: Deep Neural Network

What is MapWorks?

ZENRIN
Maps to the Future

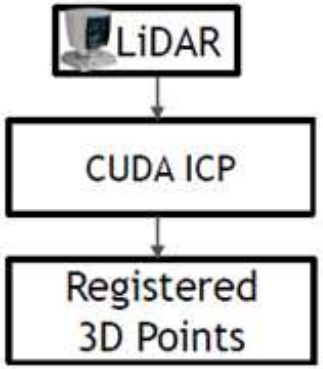
- **NVIDIA's high performance mapping SDK**
- **GPU optimized data processing**
- **Advanced AI (DNN) for mapping**

MAPWORKS SDK	DETECTION	LOCALIZATION & MAPPING	COMPRESSION	VISUALIZATION
	Detection/Classification	SfM & Stereo Reconstruction	Image & Video Compression	Point Cloud Visualization
	Primitive Extraction	Point Cloud Processing	Point Cloud Compression	HD Map 3D Visualization
	Sensor Fusion	Automatic Annotation of Fused Data	Sensor Data Input	
	Segmentation & Identification	Registration		

MapWorks: Point Cloud Registration

ZENRIN
Maps to the Future

CUDA ICP



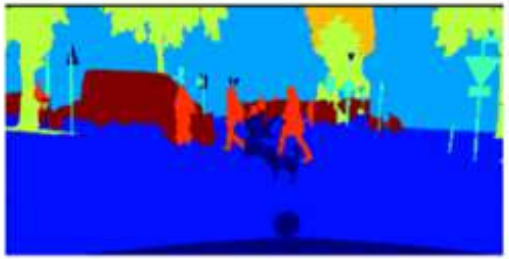
- Ubuntu, CUDA 8
- GP104 (2048 cores) - 1.6Ghz
- CPU Core i7-6700HQ - 2.8Ghz
- CUDA ICP vs CPU PCL
- 1 pair of frames registered
- Point to Plane ICP
- Filtered input of 3000 points

GP104	CPU (PCL)	GPU (CUDA)	Speedup
Time (ms)	75-80	16	4.6X - 5X

MapWorks: Detection/Classification

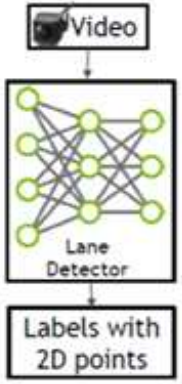
ZENRIN
Maps to the Future

DETECTION



LANE DETECTION

- Ubuntu, CUDA 8, TensorRT
- GP104 (2048 cores)
- 960x544 (RGB image)
- DNN trained for DriveWorks

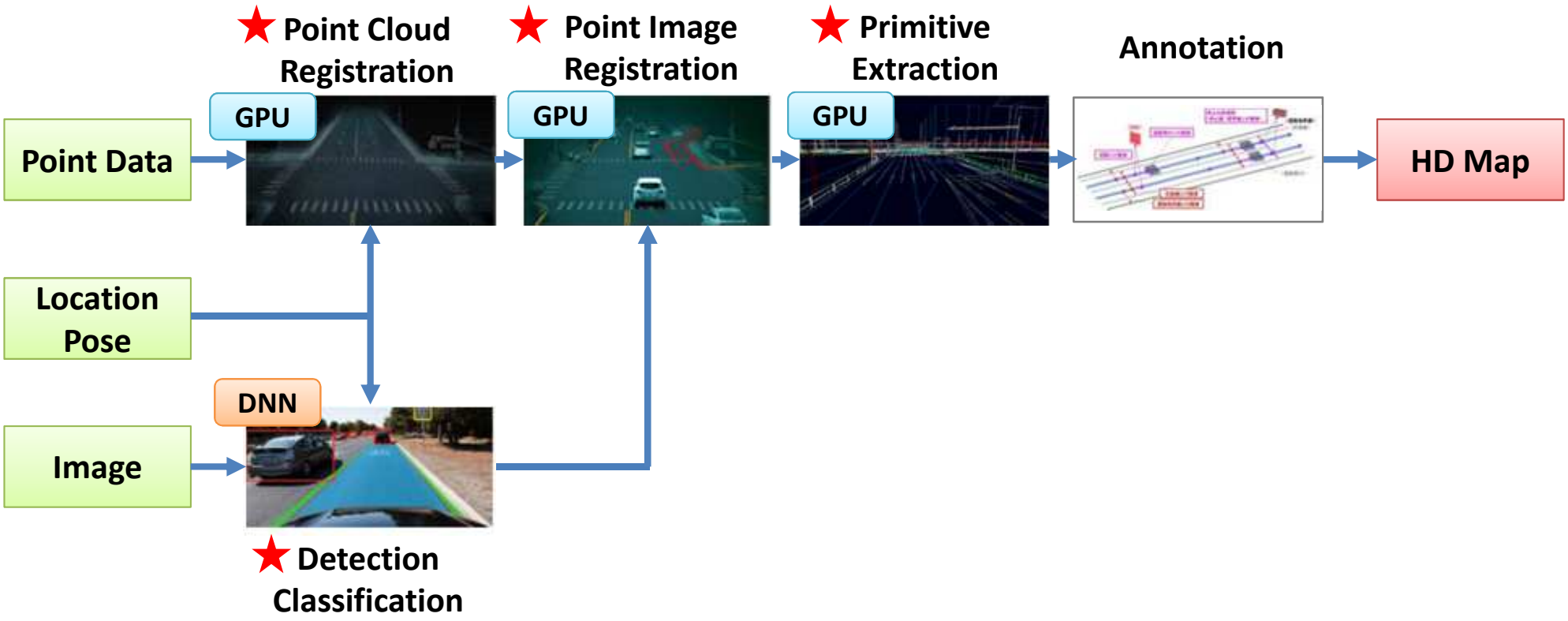


GP104	Data I/O	Inference	ALL+Visual
Time (ms)	7.7	1.0	35

Concept of the new HD map creation pipeline

ZENRIN
Maps to the Future

★: MapWorks Modules



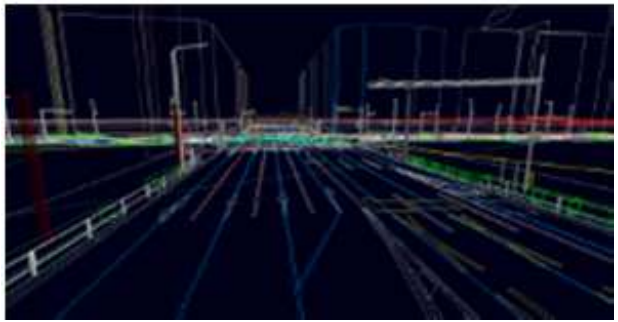
MapWorks: NV Comp

ZENRIN
Maps to the Future

Point Cloud Registration

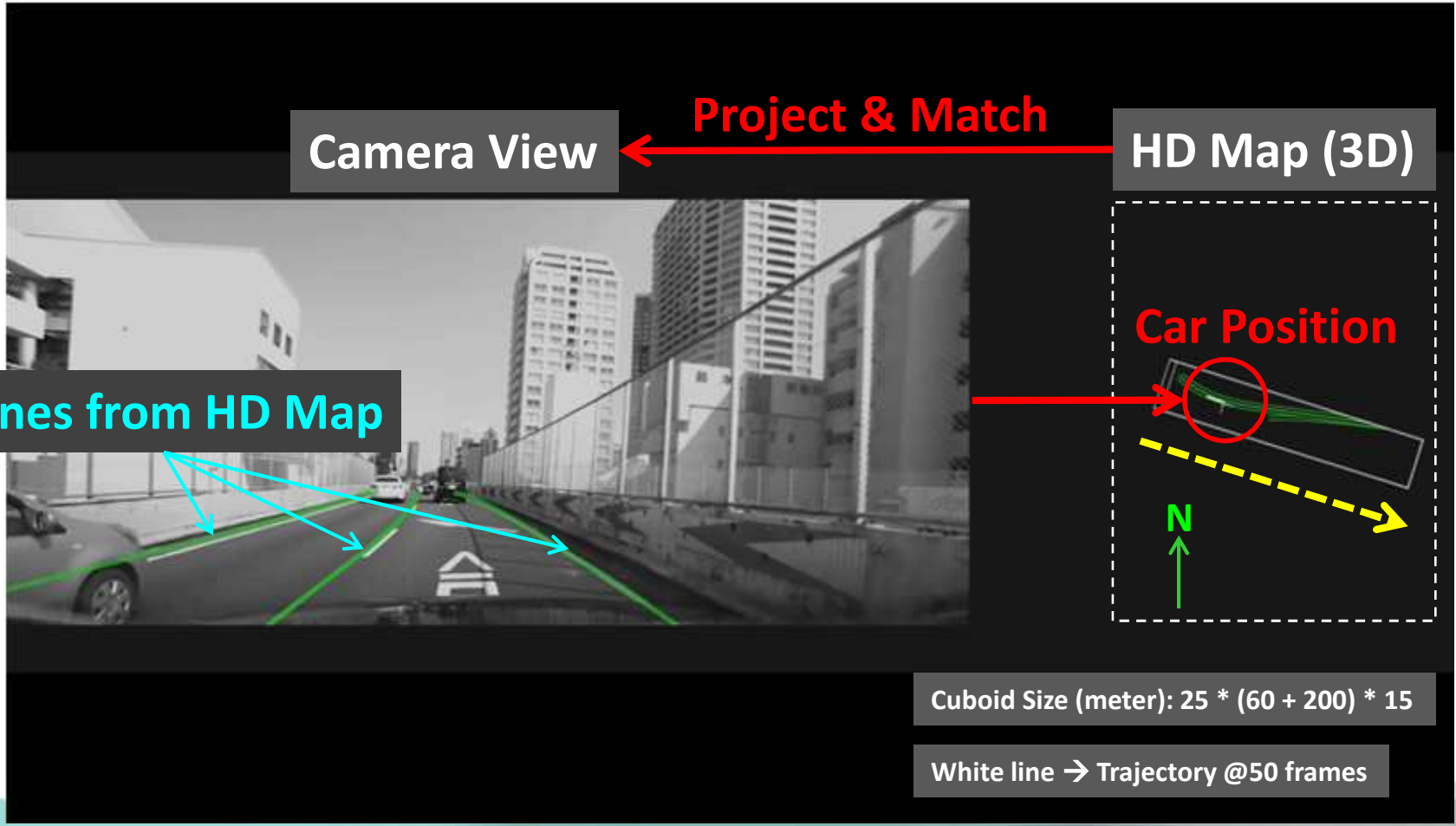
Point Image Registration

Primitive Extraction



- **Processed with loss-less compression data format (NV Comp) from Velodyne LiDARs**
- **Saves memory footprint**
- **Maximizes the GPU throughput**

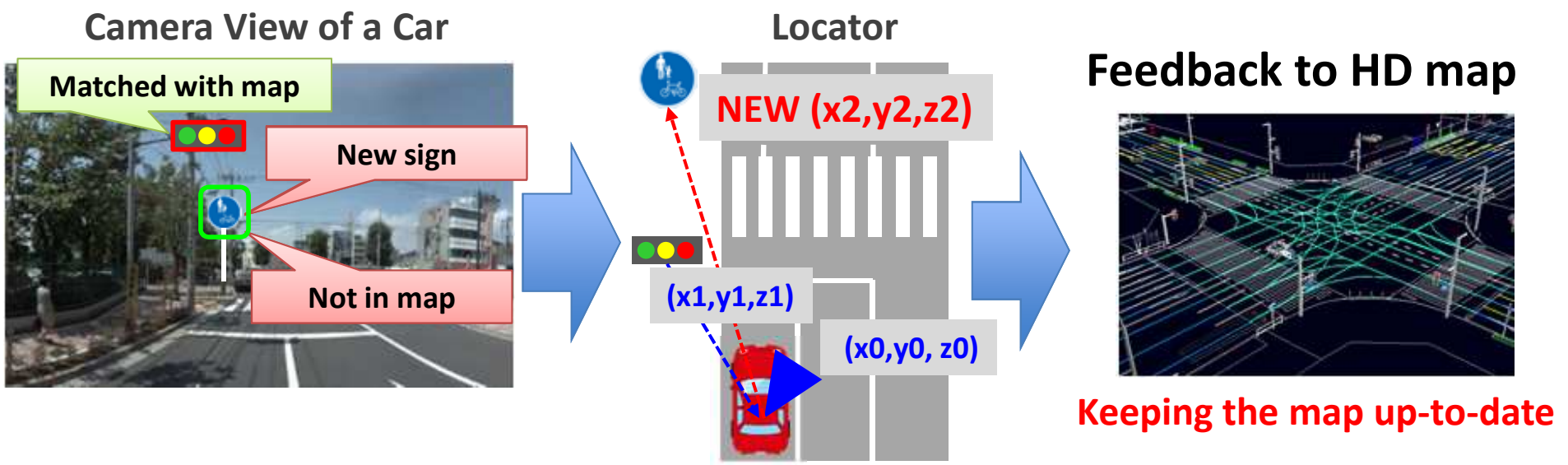
Demo: NVIDIA's locator with ZENRIN HD Map



Using feedbacks from locators to update the HD map

ZENRIN
Maps to the Future

- **Reliable and precise locators can detect real world changes and feed back to HD maps**



Proof-of-concept: Mapping Japan

Can the DNN trained in US understand Japan roads scenes?

ZENRIN
Maps to the Future

Japan road preliminary benchmark: Traffic Signs

ZENRIN
Maps to the Future

Test Data

A

Minato-ku, Tokyo Area
Approx. 1600m

B

Arakawa-ku, Tokyo Area
Approx. 350m

C

Mito-city, Ibaragi
Approx. 550m

Results

Number of Signs	116
Precision Rate	24.46%
Recall Rate	68.10%

True Positive	79
False Positive	244
False Negative	37

Discussion on the False Positive detections

ZENRIN
Maps to the Future

False Positive Samples	US Traffic Signs
	

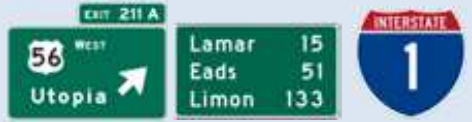
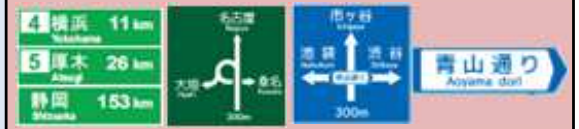
- **DNN is trained with US traffic signs: Square board with texts & symbols**

→DNN probably detecting Japanese commercial sign boards as signs.

→Japan general roads in urban areas are full of billboards.

Discussion on the False Negative detections

ZENRIN
Maps to the Future

Sign Category	Recall Rate	US Style	JP Style
Guidance	28/29		
Warning	6/6		
Designation	2/3	N/A	
Regulatory	35/58		
Auxiliary	8/20		

Square-Text vs Round-Symbols

Both challenging

False Negative detections of Regulatory Signs

ZENRIN
Maps to the Future

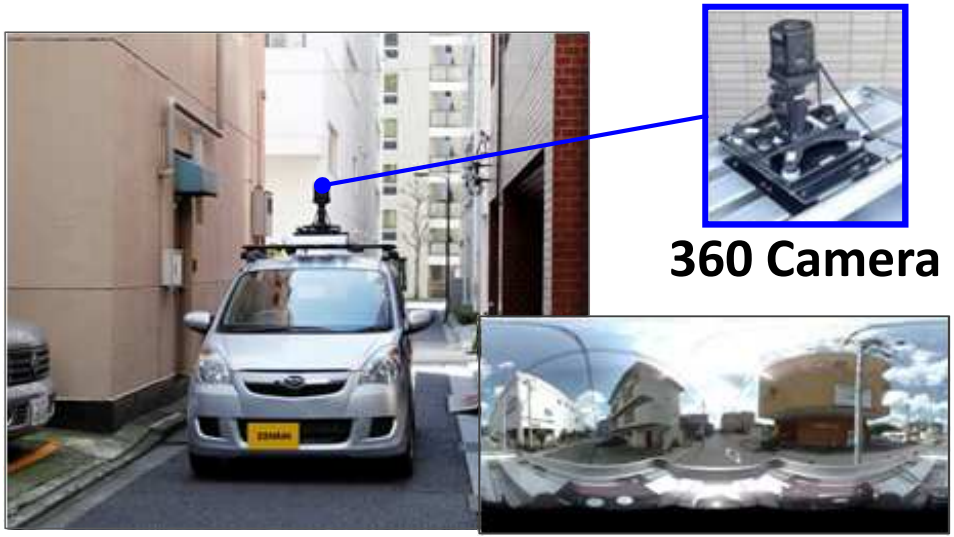
Examples

General Image processing issues	Occlusion	14
	Illumination Change	
	Segmentation	
	Scaling	
	Rotation	
	Translation	
Others	Possible untrained data style	9
Total		23

Future Work: Study & NN training with ZENRIN JP road Bigdata

ZENRIN
Maps to the Future

- **Total: 800M JPG geo-tagged images of JP roads**
- **2Mkm drive. Photo taken every 2.5m**
- **Toll free narrow roads nationwide.**



360 Camera

Panoramic Photo

Traffic Signs

Conclusion

Conclusion

ZENRIN
Maps to the Future

- **GPUs and AIs can accelerate and automate the creation and updating of HD maps**

- **Optimizing the pipeline to Japan roads with ZENRIN's mapping experience, knowledge and big data**

→Still have many technical challenges. Looking forward to discussing solutions and collaborating with you!

Acknowledgement to:

Naoyuki Yura, Katsuya Misu, Kenichi Yoshii & Leonid Terenin

NVIDIA Japan

Thank You

Shigeyuki (Shawn) Iwata

shigeyuki@zenrin.com