AUTOMATED EXTRACTION OF ROAD SURFACE INFORMATION FROM MOBILE LIDAR

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June 17, 2014

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PRESENTATION OUTLINE

1. Introduction to Mobile LiDAR or MLS
2. Why Mobile LiDAR or MLS?
3. Road Surface Information Extraction
4. Concluding Remarks
5. Acknowledgements
6. Published Papers

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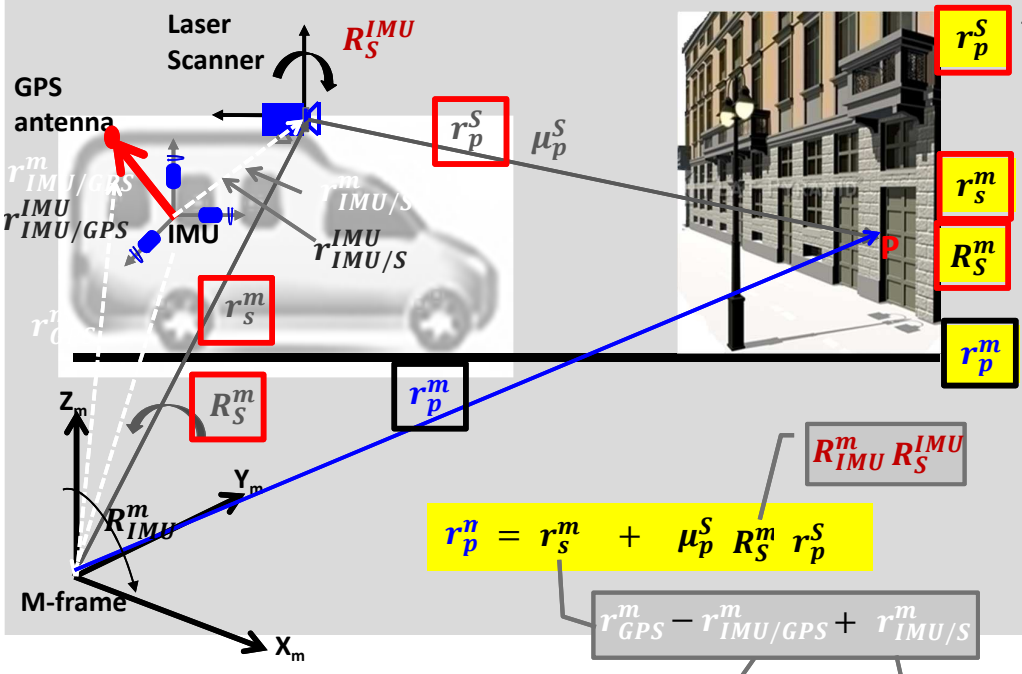
CURRENT MLS SYSTEMS

- 3D Laser Mapping: StreetMapper (2005), StreetMapper 360 (2011)
- Optech: Lynx Mobile Mapper (2007), Lynx SG1 (2013)
- Riegl:VMX-250 (2009), **VMX-450** (2011)
- SITECO: Road-Scanner (2009)
- Topcon: IP-S2 (2009), IP-S2 Compact+ (2012)
- Trimble: MX8 (2010)
- MDL Laser Systems: Dynascan (2010)

DIRECT GEOREFERENCING



r_p^S The position of object P in laser scanner coordinate system

r_s^m The position and orientation of laser scanner in the local coordinate system

R_S^m

r_p^m The position of Object P in the local coordinate system

$$r_p^m = r_s^m + \mu_p^S R_S^m r_p^S$$

$R_{IMU}^m R_S^{IMU}$

$r_{GPS}^m - r_{IMU/GPS}^m + r_{IMU/S}^m$

$R_{IMU}^m r_{IMU/GPS}^{IMU}$

$R_{IMU}^m r_{IMU/S}^{IMU}$

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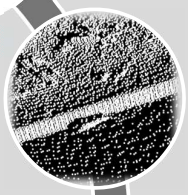
MOBILE LIDAR

System	Road Scanner	IP-S2	MX8	VMX-450	StreetMa per 360	Dynascan	Lynx
Scanner	Faro Photon 120	Sick LMS 291		VQ-450		MDL	V100
Max. range	120m (ρ90%)	80m (ρ10%)		800m (ρ80%)		up to 500m	200m (ρ80%)
Range precision	1mm@ 25m, ρ90%	10 mm @ 20 m		5mm @150m (1σ)			8mm,1σ
Range accuracy	±2mm@25m	±35mm		8mm @150m (1σ)		±5cm	±10mm (1σ)
PRR	122- 976 kHz	40kHz		2 x 550 kHz		36 kHz	2 x 500 kHz
Scan speed	48Hz	75Hz		2x 400 Hz		30 Hz	2x 100 Hz
Scanner FOV	H360º / V320º	180º / 90º		360º without gaps		360º	360º
Angular resolution	H0,00076° / V0,009º	1º / 0,5º		0,001º		0,01º	0,001º
Weight	14.5 kg	22.7kg		11kg		11kg	78 kg

MLS POINT CLOUD

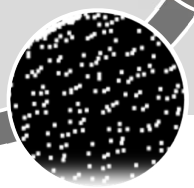
Large Scale Unorganized 3D Point Cloud

Data Size
5GB per km



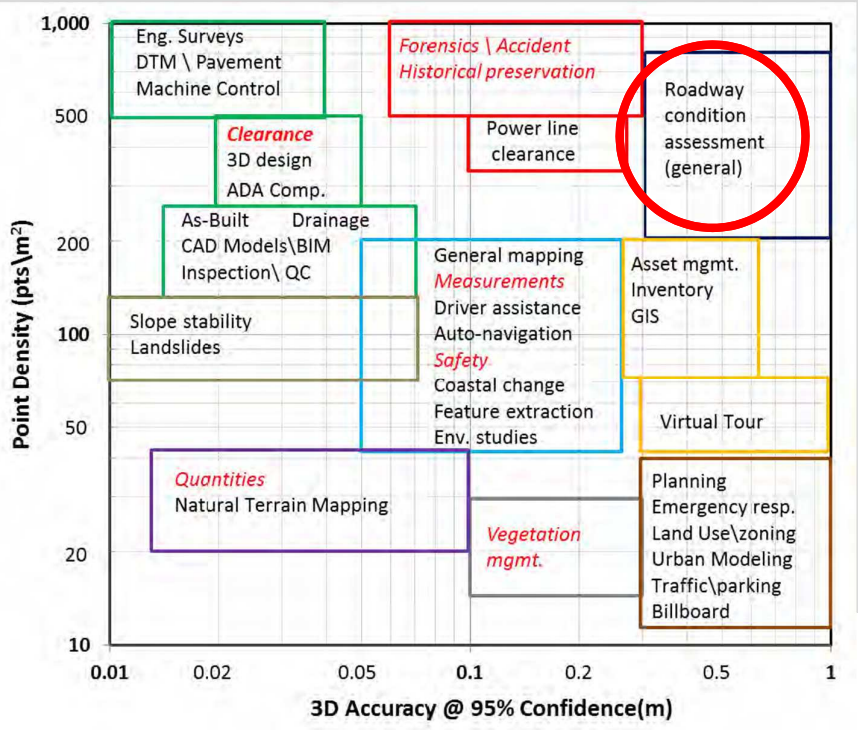
Density
2K pints / m^2

Acquisition
30~100 km/h



Unorganized Distribution

ACCURACY REQUIREMENTS



The orders of accuracy:
1 = High (**< 0.05 m**)
2 = Medium (**0.05 - 0.20 m**)
3 = Low (**> 0.20 m**)

The levels of point density :
A = Fine (**>100 pts/m²**)
B = Intermediate (**30 - 100**)
C = Coarse (**<30**)

Reference: NCHRP 15-44 GUIDELINES FOR THE USE OF MOBILE LIDAR IN TRANSPORTATION APPLICATIONS.

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RESOLUTION REQUIREMENTS

- **Point cloud density (resolution)** is determined by two factors:
- **Measurement distance**: 7000–8000 pts/m² (1 m), 800–900 (10 m), 80–90 (100 m), 50-60 (120 m), by a VMX-250 or MX8 at speed of 50 km/hr; 5000-6000 (1m), 400-500 (10m), 40-50 (100m), 20-30 (120m) at 120 km/hr.
- **Driving speed:** 0.15 m in scan line spacing at 50 km/hr, 0.35m at 120 km/hr.

PROBLEMS FOR RAPID ACQUISITION OF ROAD SURFACE INFORMATION






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WHY MOBILE LIDAR OR MLS?

10 sq km/hr

0.1 sq km/hr

Speed of data capture

Trends in technology migration

Airborne Laser Scanning (ALS)

Mobile Laser Scanning (MLS)

Terrestrial Laser Scanning (TLS)

€100k

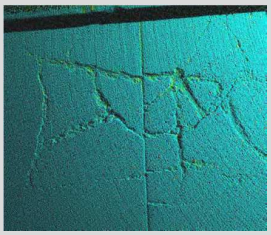
Capital cost

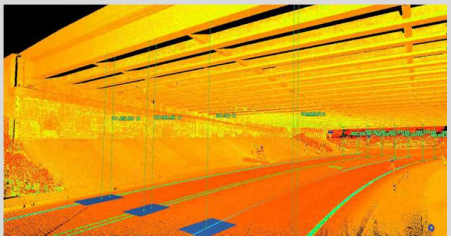
€600k

€400-500k

TRANSPORTATION APPLICATIONS OF MOBILE LIDAR

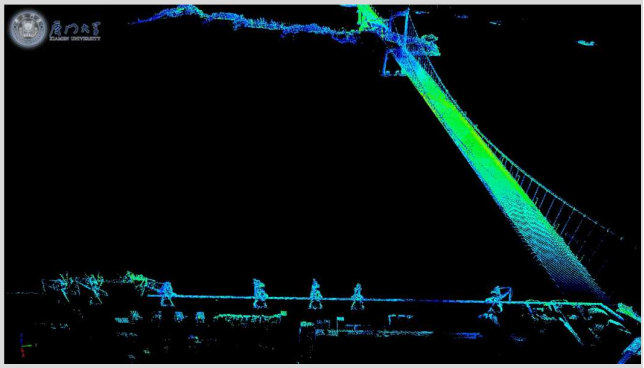
- **Roadways**
  - » Road topo for design
  - » Intersections
  - » Pavement QA
  - » Road topo for problem analysis
  - » Paving volumes
  - » Input to road milling
  - » Accident investigation & analysis
  - » Slope stability & retaining wall surveys
  - » Toll Plazas

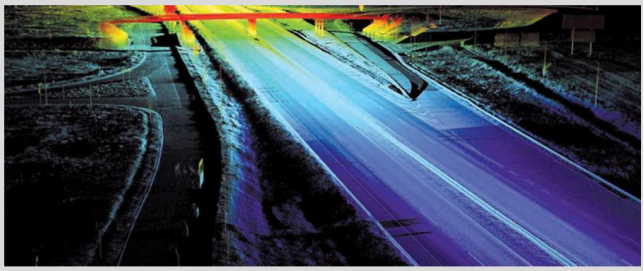




TRANSPORTATION APPLICATIONS OF MOBILE LIDAR

- **Bridges and elevated roads**
  - » Design as-builts
  - » Clearances
  - » Topo for problem analysis
  - » Heritage





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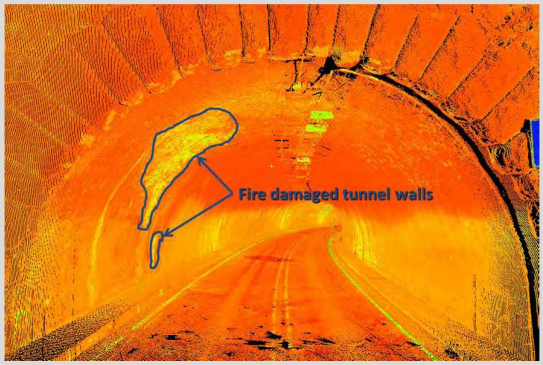
TRANSPORTATION APPLICATIONS OF MOBILE LIDAR

- **Tunnels**
  - » Profiles
  - » Pavement QA & quantities
  - » Clearances



RESULTS FOR ROAD SURFACE INFORMATION EXTRACTION

- Road information (road markings, pavement crakes, manholes, etc.)
- Non-road information (light-poles, trees, cars, power-lines, etc.)

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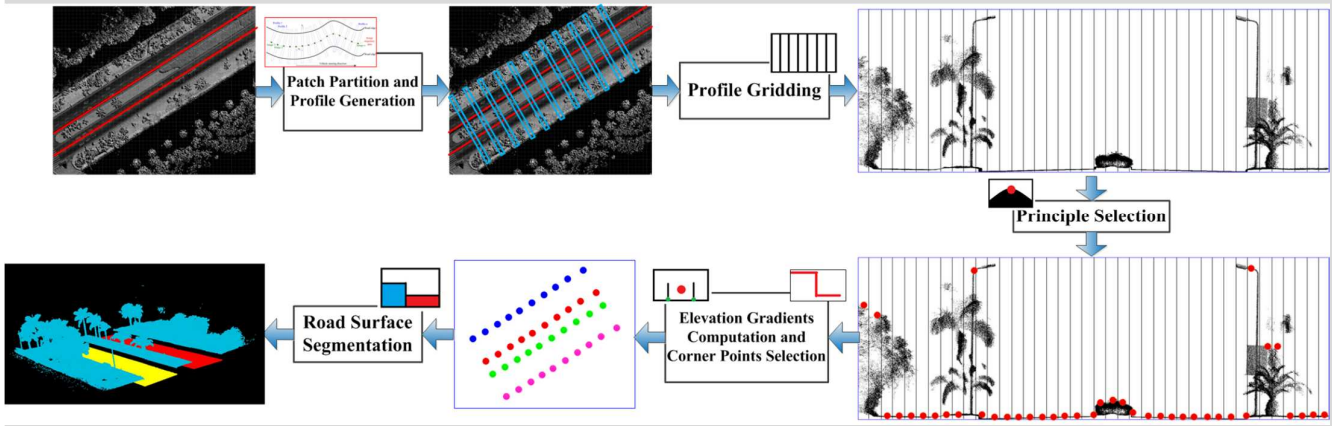
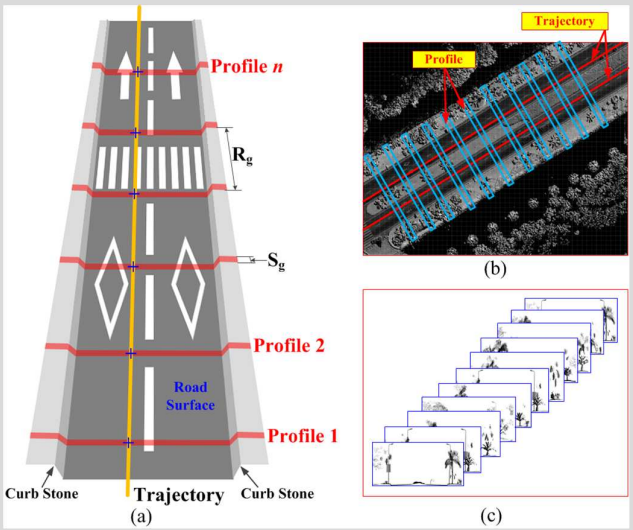
ROAD SURFACE EXTRACTION

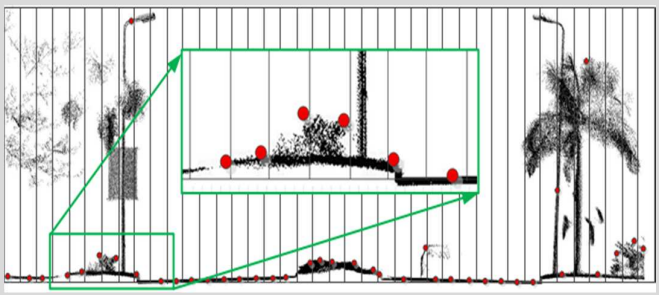


1) Point cloud data profiling
2) Profile gridding and principal point generation
3) Curb corner point detection
4) Road edge interpolation and road surface extraction

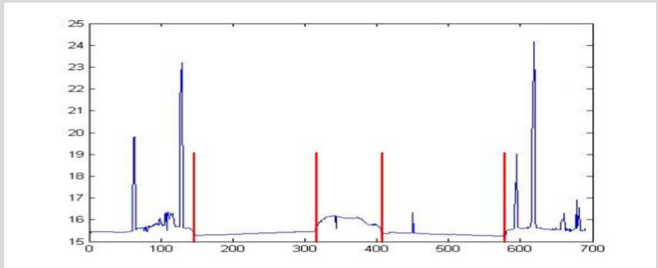
PROFILING & CURB CORNER POINT DETECTION



(a) Data profiling model;
(b) Profile generation in real point clouds;
(c) Generated profiles;

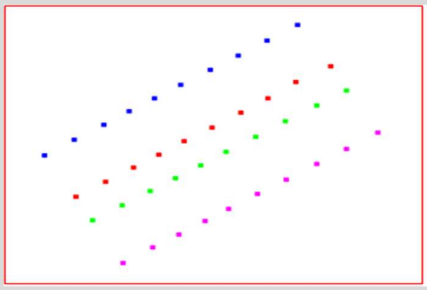


Profile gridding and principal point generation

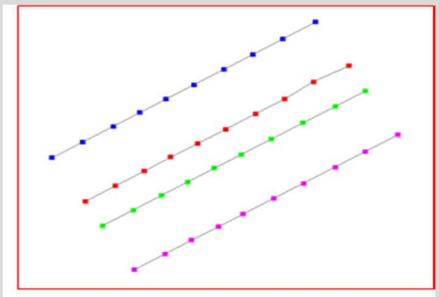


Detected curb corner points

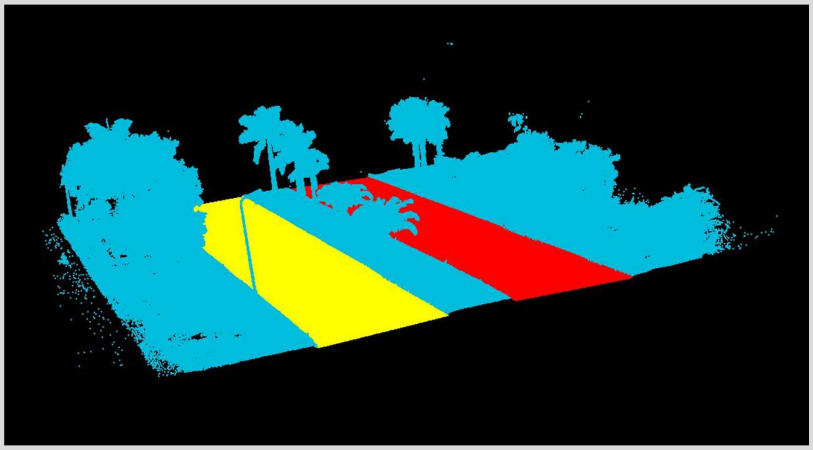
CURB-LINE INTERPOLATION & ROAD SURFACE EXTRACTION



Curb corner points from all profiles.

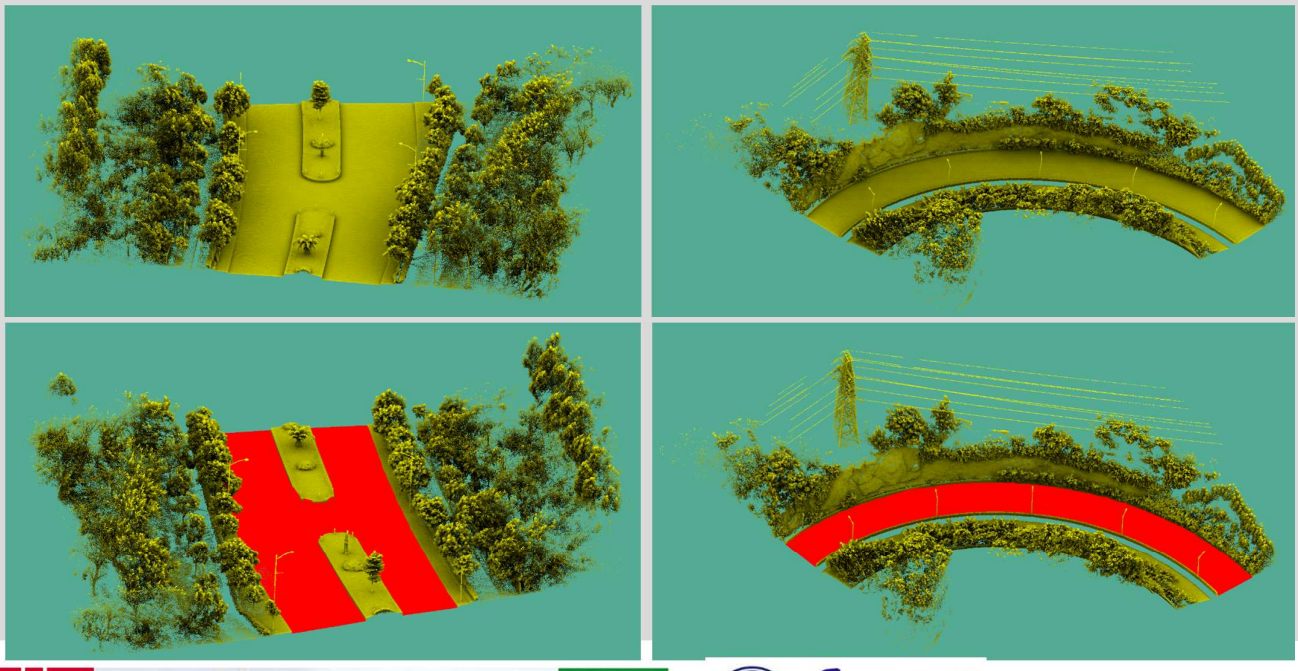


Interpolated curb-lines.



Extracted road surfaces

ROAD SURFACE EXTRACTION



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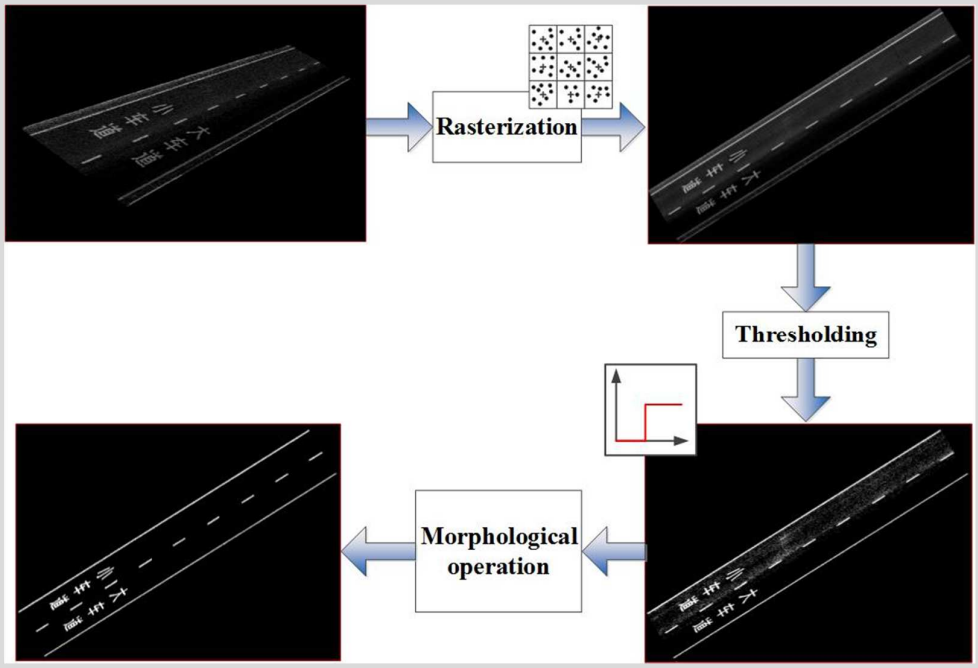
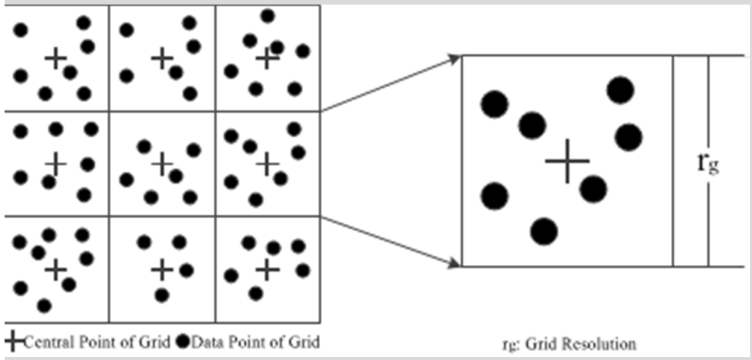
2D ROAD MARKING EXTRACTION



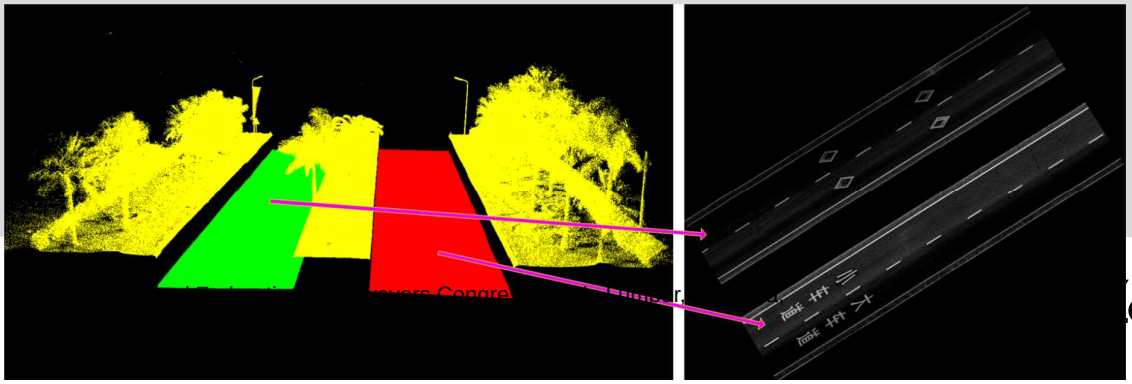
1. Generation of geo-referenced intensity image
2. Thresholding
3. Extraction of road markings

GEO-REFERENCED INTENSITY IMAGE GENERATION

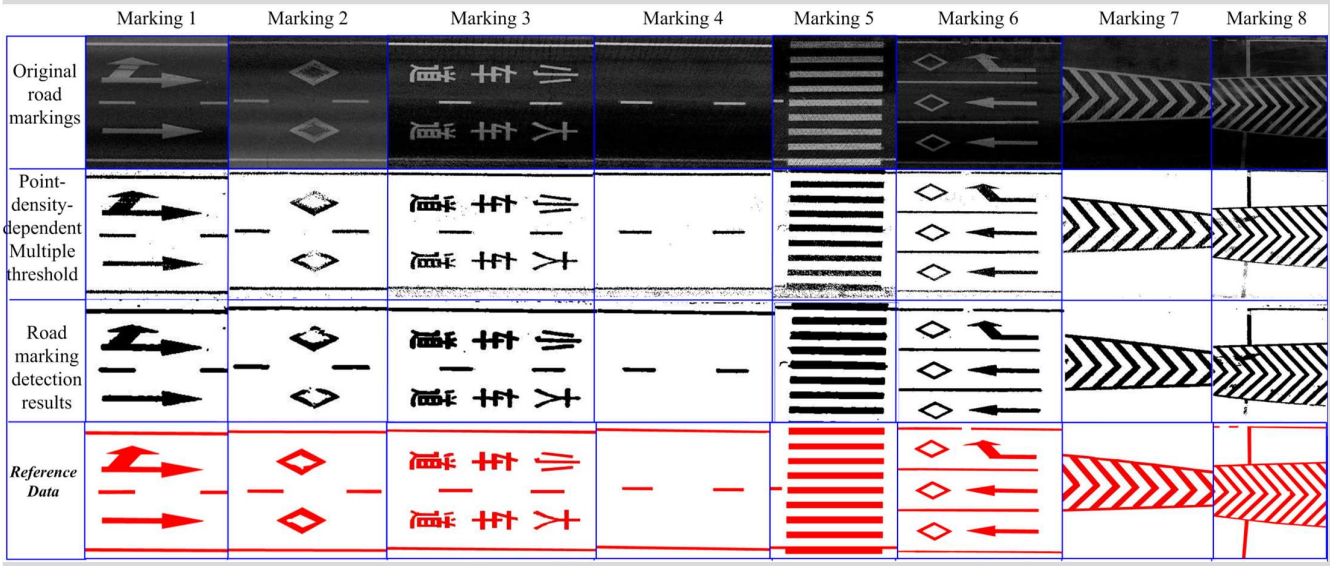


Geo-referenced intensity image generation model

$$\begin{cases} G_{ij}^{I} = \left(\sum_{k=1}^{n_{ij}} W_k^{ij} I_k^{ij}\right) \Big/ \left(\sum_{k=1}^{n_{ij}} W_k^{ij}\right) \\ W_k^{ij} = \alpha W_{k,ij}^{D} + \beta W_{k,ij}^{I}, \ with \ \alpha + \beta = 1.0 \end{cases}$$



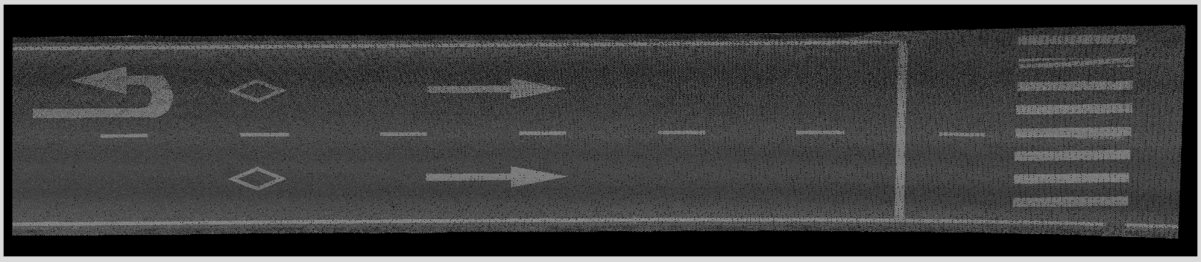
ROAD MARKING EXTRACTION



ROAD MARKING EXTRACTION IN 3D

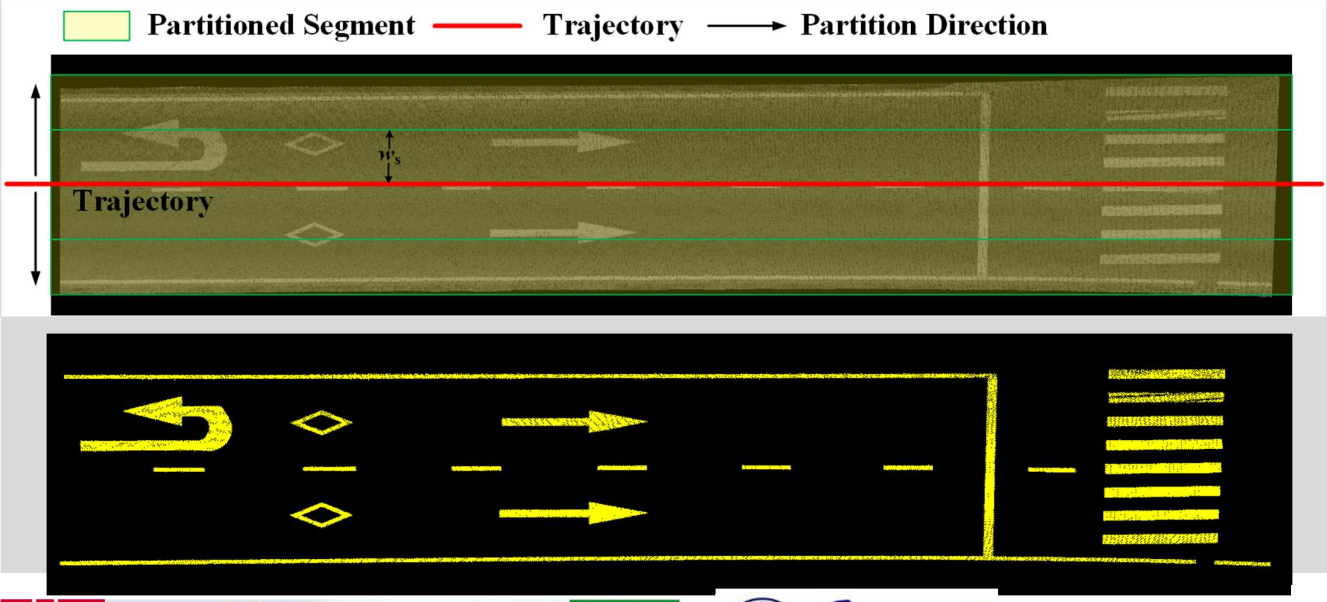
Road surface extraction

Extracted road surface points



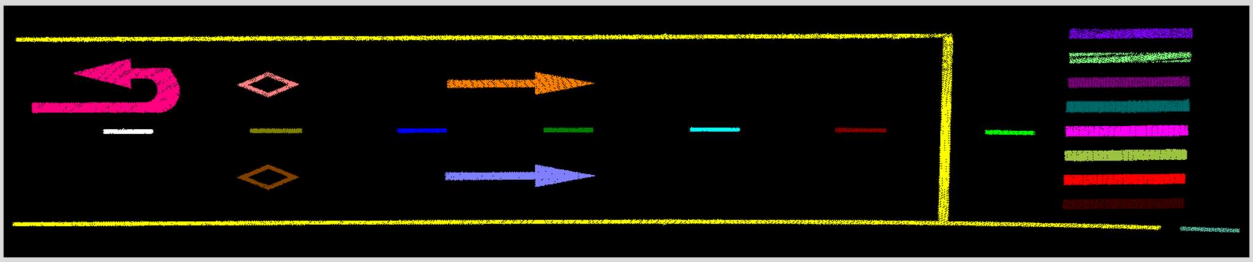
ROAD MARKING POINT EXTRACTION

Road marking points extraction using multi-segment thresholding

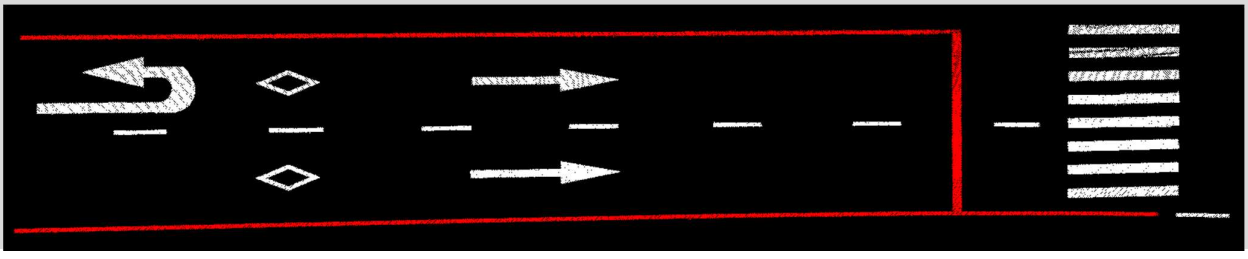


ROAD MARKING CLASSIFICATION

Road marking points clustering



Detected large-size road markings



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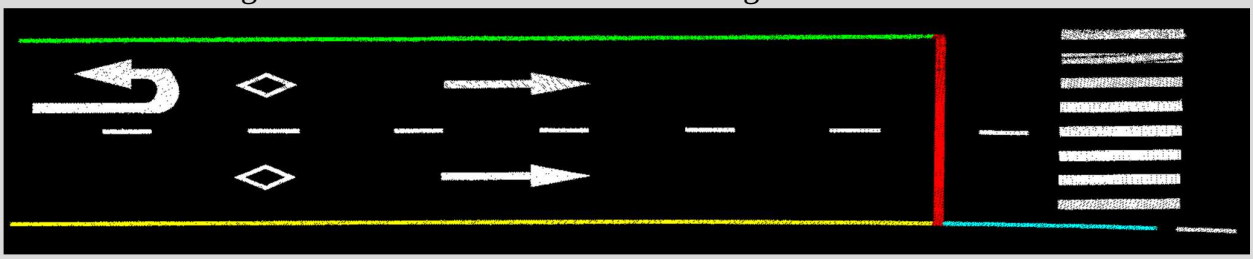
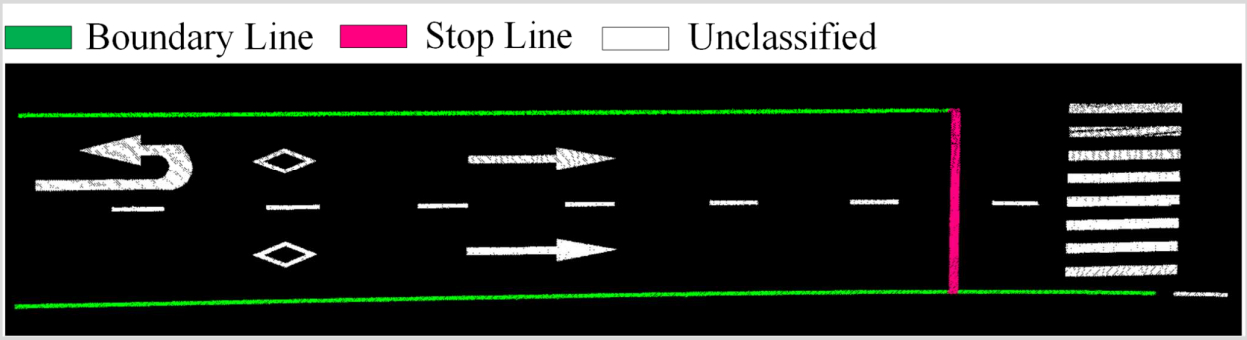
ROAD MARKING CLASSIFICATION

Normalized cut segmentation on connected road markings

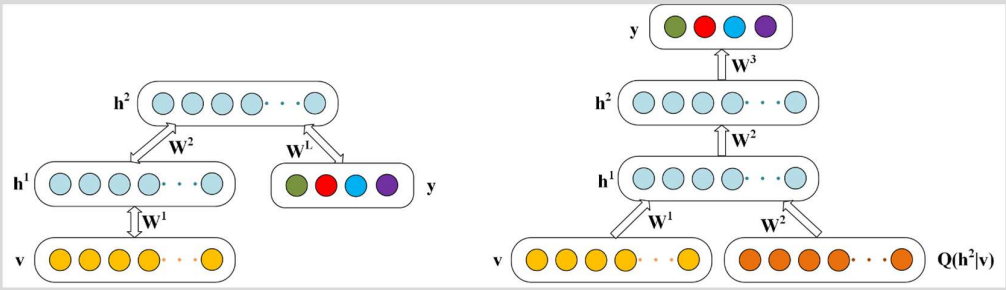


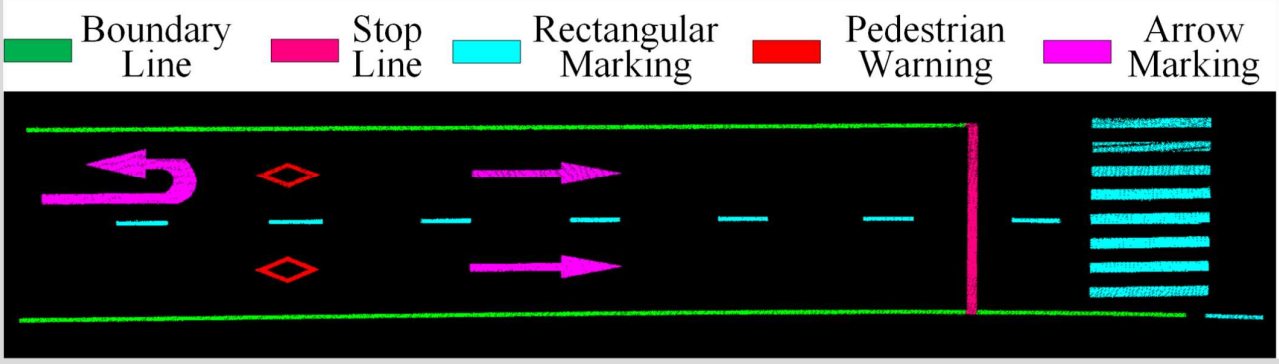
Large-size road marking classification



ROAD MARKING CLASSIFICATION

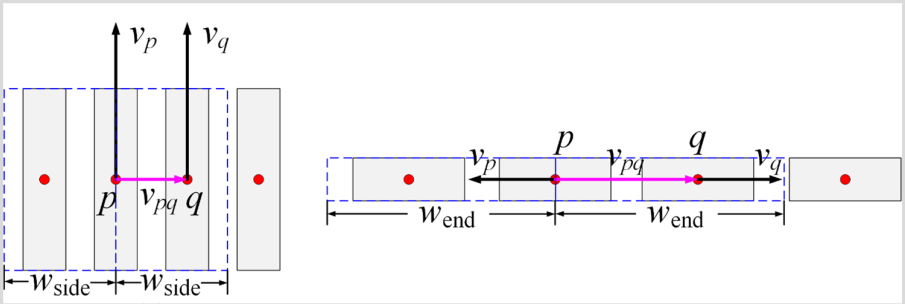
Deep learning based small-size road marking classification

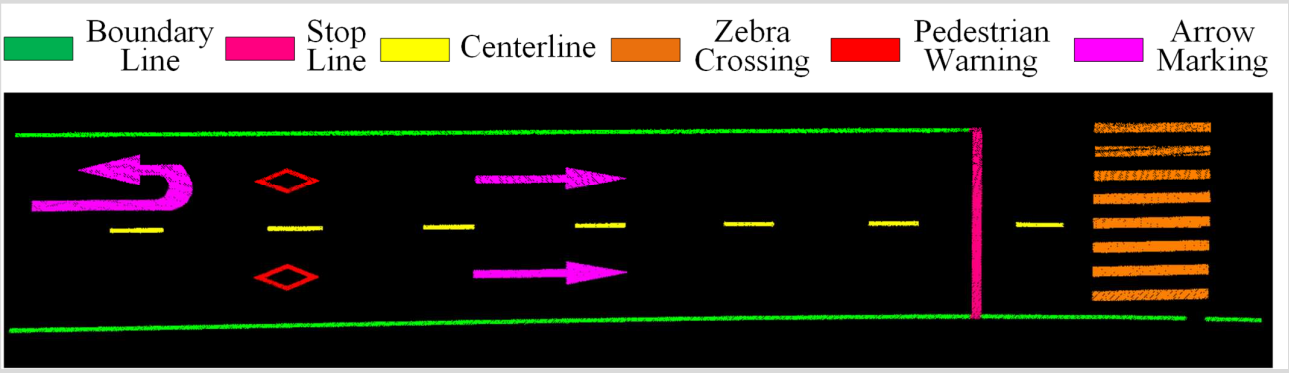




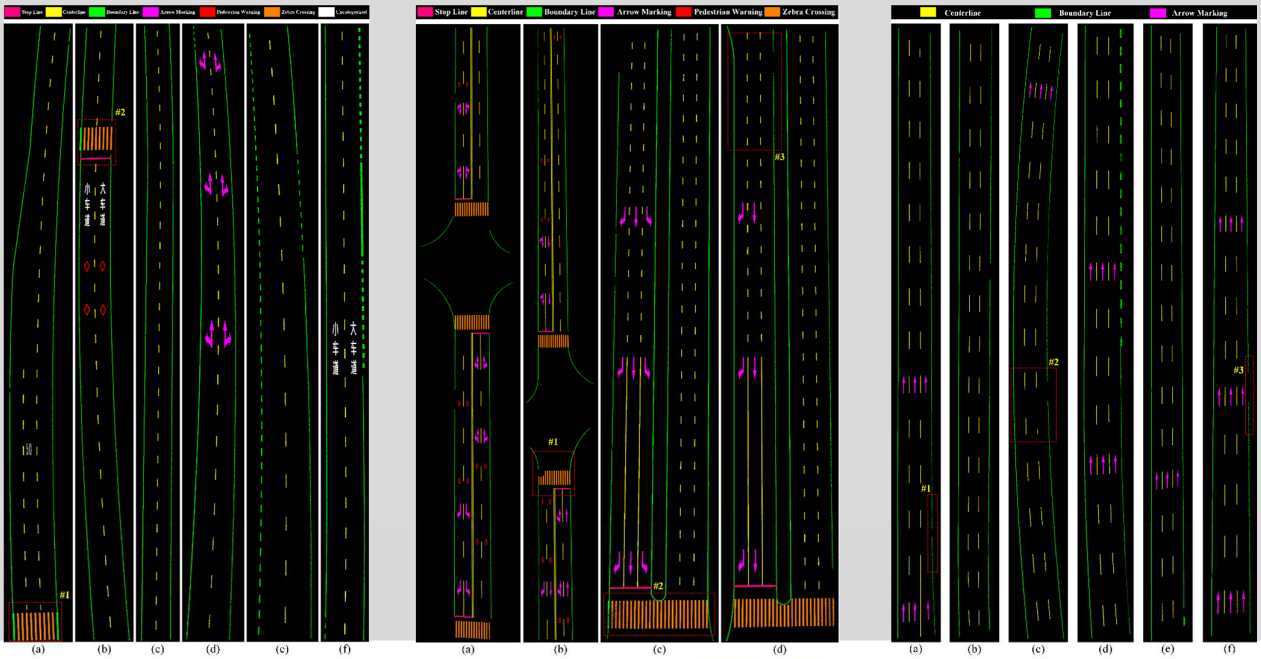
ROAD MARKING CLASSIFICATION

PCA-based zebra crossing and dashed line classification





ROAD MARKING CLASSIFICATION



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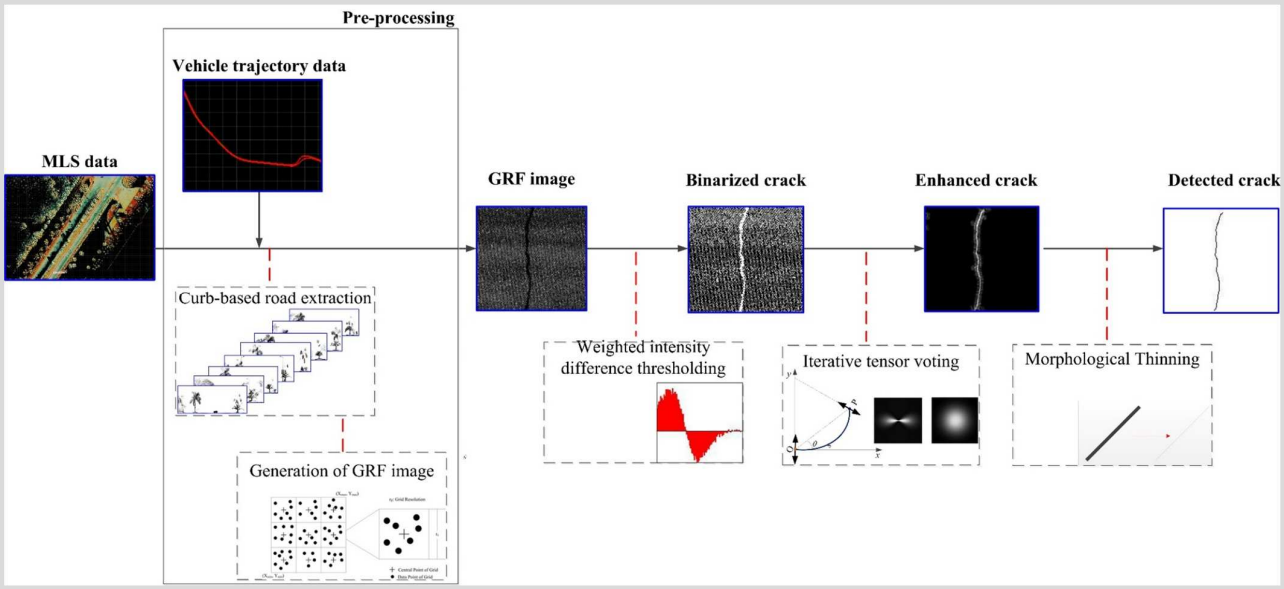
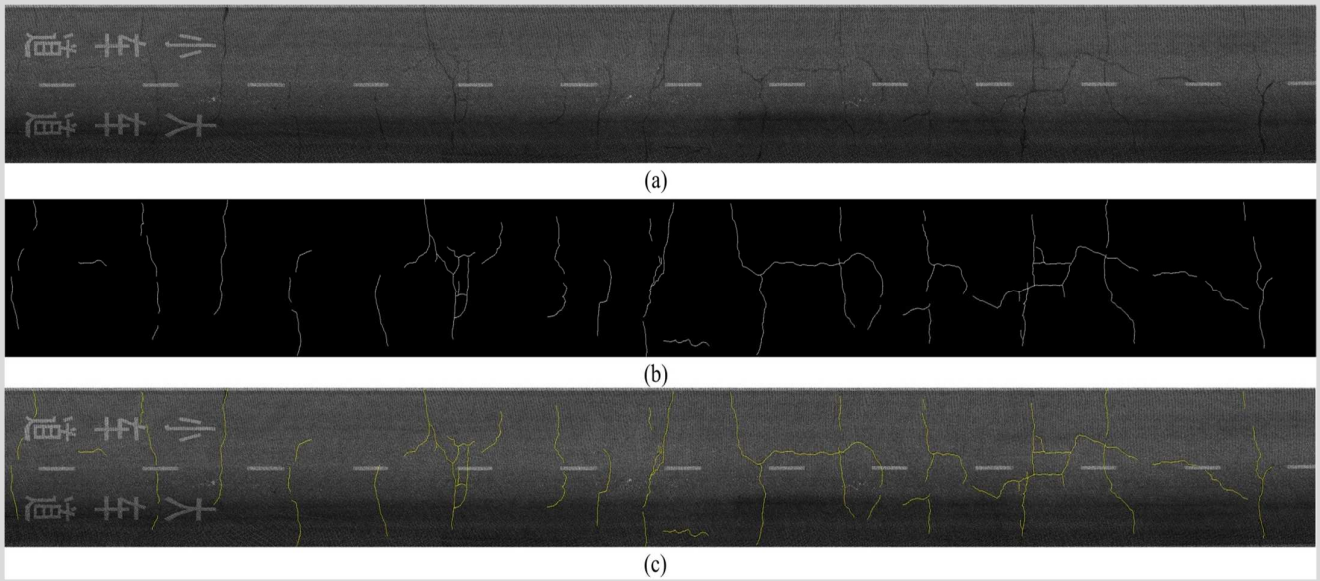
PAVEMENT CRACK EXTRACTION



CRACK EXTRACTION RESULTS



(a) Geo-referenced intensity image, (b) extracted cracks, and (c) overlaid result.

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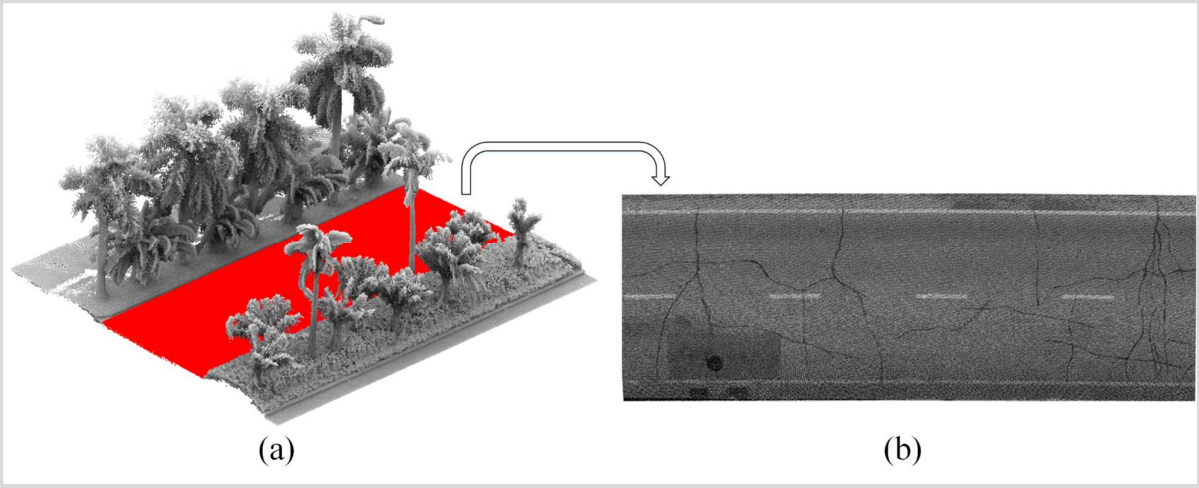
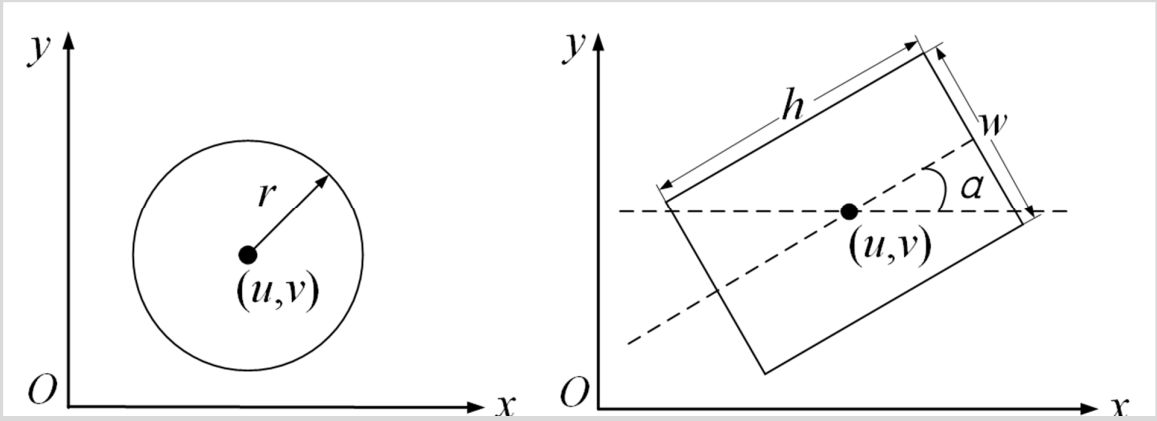
ROAD MANHOLE DETECTION



(a) Extracted road surface and (b) geo-referenced intensity image.

ROAD MANHOLE DETECTION

Road manhole detection based on marked point process of rectangles and disks.

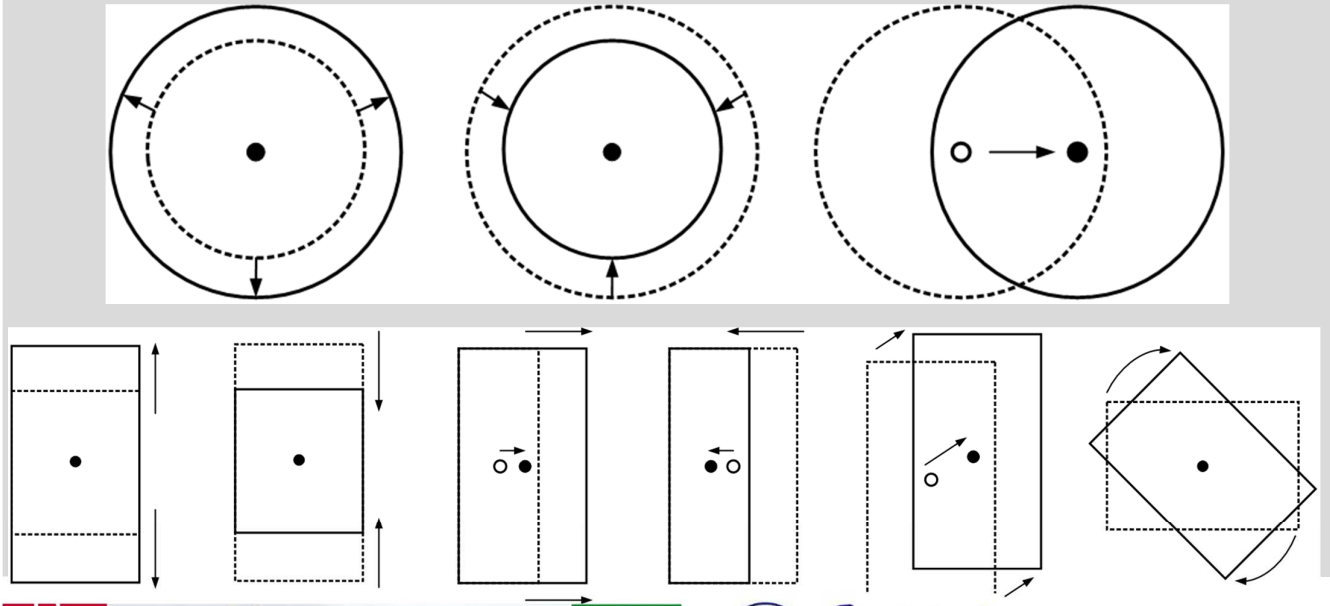


Mark point of disk.

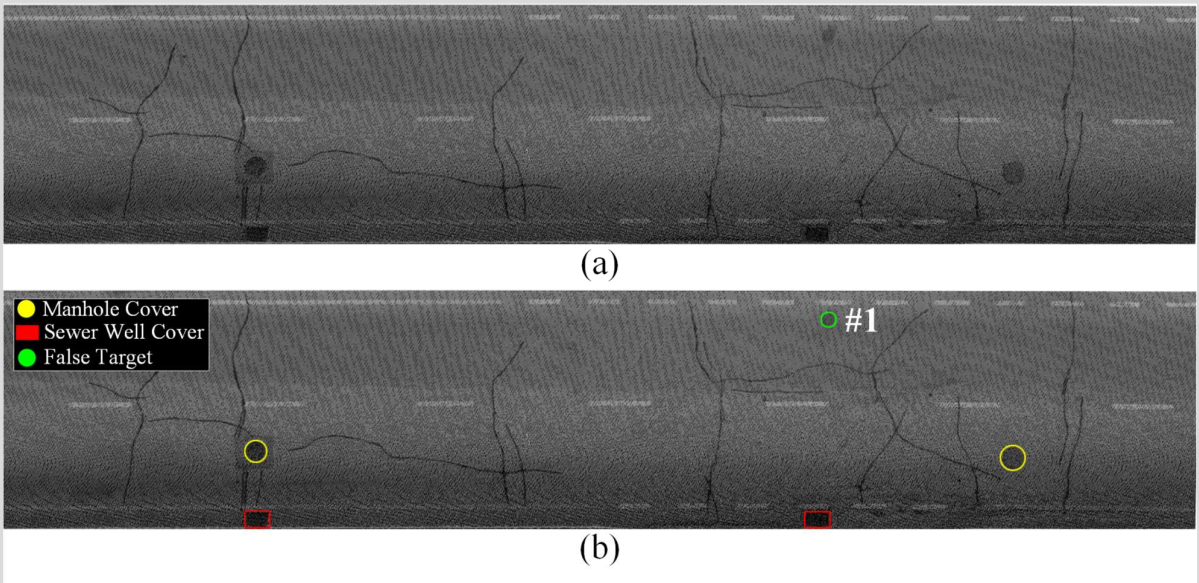
Mark point of rectangle.

ROAD MANHOLE DETECTION

Transformations of mark points.



ROAD MANHOLE DETECTION



(a)

(b)

(a) Geo-referenced intensity image and (b) road manhole detection result.

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CONCLUDING REMARKS

- With a MLS system, mobile mapping crew can drive a highway, rural road, railroad, or on the shoreline of a river or lake.
- Along the way, the system captures virtually anything visible to the eyes in 3D. The collected data are a totally immersive 3D view of objects and surroundings.
- Today's major trend in mapping and GIS is an increasing demand for not only accuracy of geospatial data but efficiency and low cost.
- MLS systems can meet this demand and provide the end results with increased productivity.

CONCLUDING REMARKS

- MLS is a much safer mapping technique than traditional highway surveys, where surveyors wearing orange vests measure the land boundaries and understand the terrain via total stations, TLS, and so on, as well as the requirement of extensive traffic management or road closures.
- MLS is a more feasible 3D measurement technology for large-scale mapping projects than the legacy methods.
- Specifically speaking, a 10-km-long highway would have taken at least 20 nights to survey and a week to process the resultant measurements by a traditional highway survey method, while the highway, would take, from start to finish, less than a week using a MLS system.

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ACKNOWLEDGEMENTS

- NSERC and NSFC for funding support.
- UW and XMU for support;
- GeoSTARS Lab at UW and Fujian Key Laboratory of Sensing and Computing for Smart Cities (SCSC Lab) at XMU for support;
- Special thanks go to Dr. Haiyan Guan and Yongtao Yu.

PUBLISHED JOURNAL PAPERS

① Guan, H., **J. Li**, Y. Yu, and C. Wang, 2014. Automatic road information extraction using mobile laser scanning data. *IEEE Transactions on Intelligence Transportation Systems,* Doi:10.1109/TITS.2014.2328589.

② Guan, H., **J. Li**, Y. Yu, and Wang, C., 2014. Interactive tensor voting method for crack detection using mobile laser scanning data. *IEEE Transactions on Geoscience & Remote Sensing,* accepted.

③ Guan, H., **J. Li**, Y. Yu, Wang, C., Chapman, M., and Yang, B., 2014. Using mobile laser scanning data for automated extraction of road markings. *ISPRS Journal of Photogrammetry & Remote Sensing*, 87:93-107.

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QUESTIONS?