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A vision-centered multi-sensor fusing approach to self-localization and obstacle perception for robotic cars

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Key words: Visual perception; Self-localization; Mapping; Motion planning; Robotic car

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Introduction

- A vision-centered multi-sensor fusing framework for the robotic cars' perception problem is proposed, which consists of self-localization and processing of obstacles surrounding the robotic car.
- A hybrid metric-topological map in lane-level via fusion of camera, LIDAR and GPS trajectory is built, and the use the map constructed for self-location.
- A vision-centered multi-sensor fusing approach to the processing of surrounding obstacles is presented.

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Timeline of the robotic cars

Self-localization

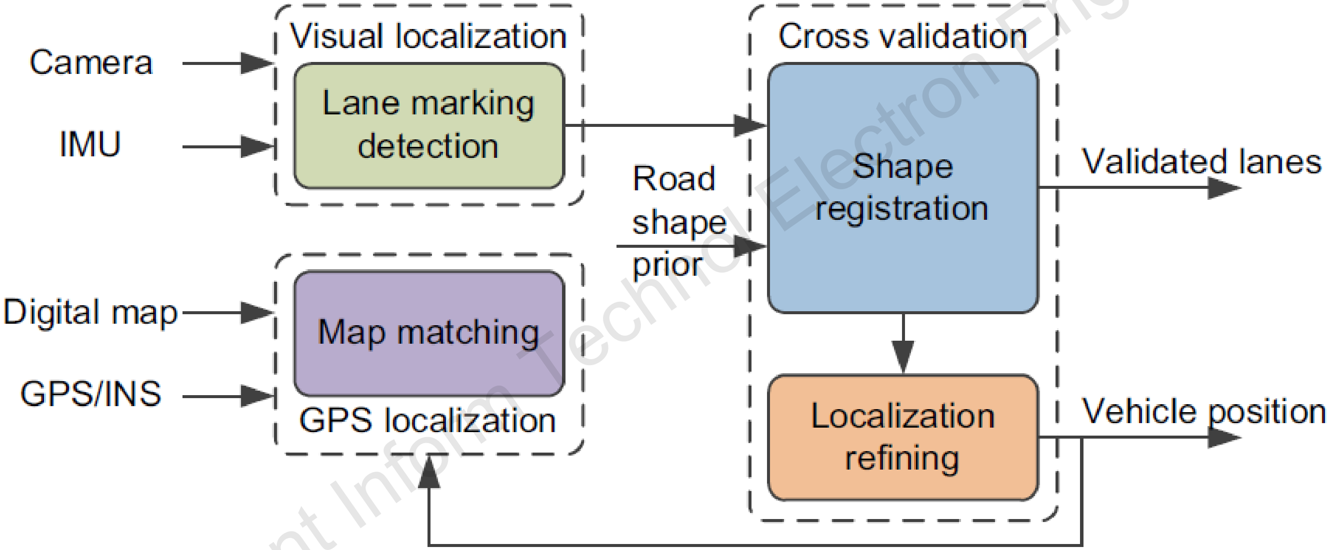

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Fig. 2 **Architecture of the proposed self-localization system**

Generation of road boundary map

- Data acquisition and preprocessing.

Piecewise linear road shape model is proposed, and a constraint least-squared (LS) is used to solve above road shape model.

- Extracting road boundaries.

Aligned detected lane marking with vehicle trajectory based on iterative closest point (ICP) algorithm.

- Generating a multi-lane map.

A consistent global multi-lane map is obtained via GraphSLAM.

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Self-localization at the centimeter level

- Visual localization.

Integrating lane marking detection with the camera pose measurements from IMU.

- GPS localization.

GPS position fixes are used as an initialization for map matching algorithm.

- Cross validation.

Fusing road shape prior, visual localization and GPS localization by a shape registration algorithm.

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Multi-lane map

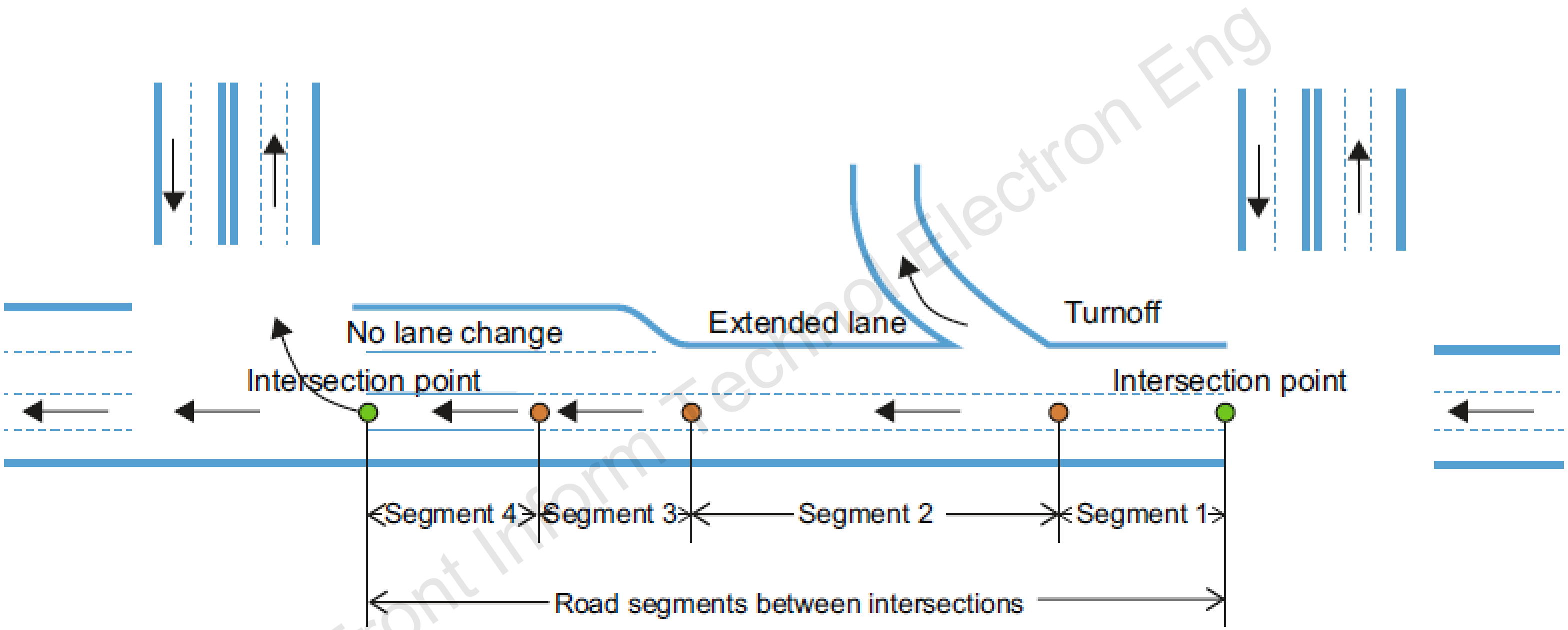

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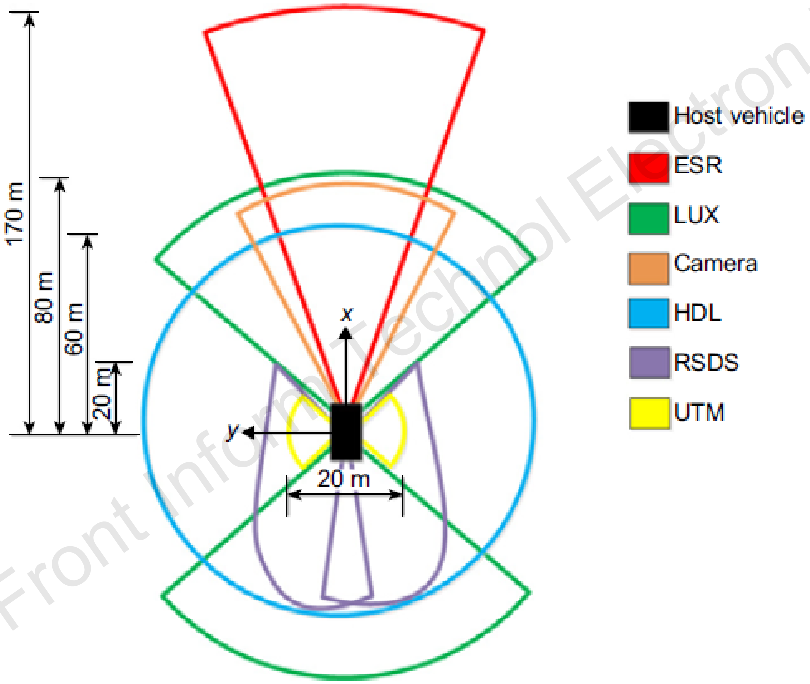
Fig. 3 The multi-lane map generated via the proposed method

Multi-sensor fusing for obstacle detection and tracking



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The sensor configuration for KUAFU-1

Calibration LIDAR with camera

Finding out a homograhy transformation.

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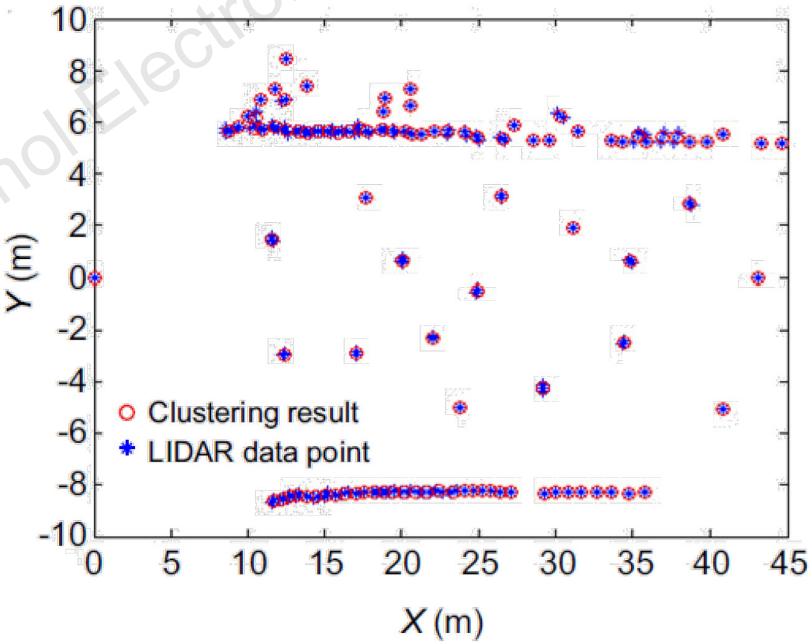
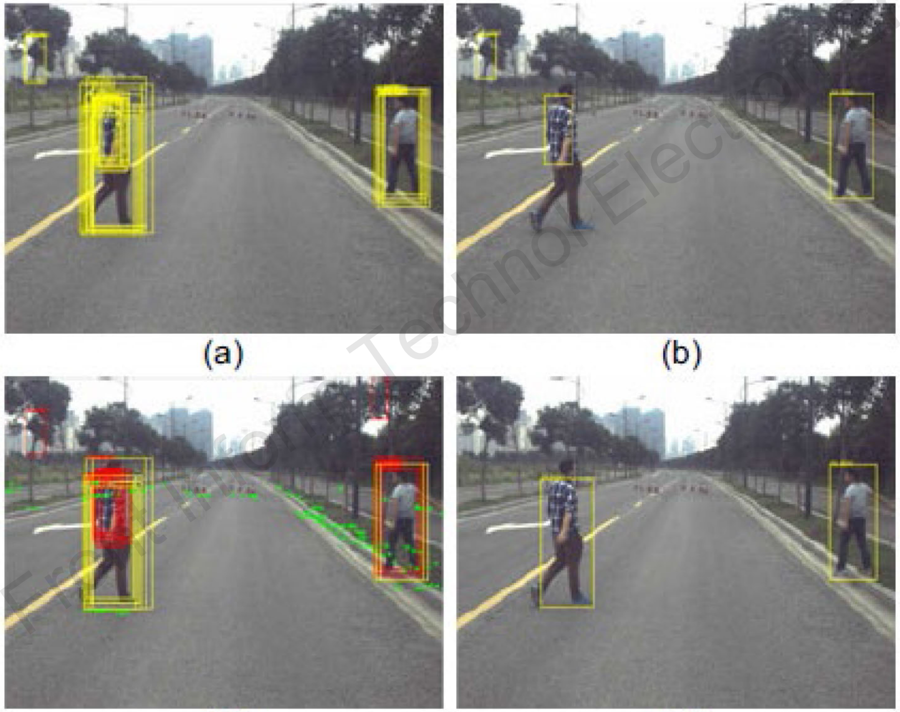


Traffic cones(upper and bottom side) are used for calibration LIDAR with camera.

Pedestrian Detection


(a) (b)

(c) (d)

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Pedestrian results: original detection, NMS without false alarm removal, height constraint, NMS with false alarm removal.

Reducing the search region

Left image: the LIDAR points are projected onto the image with a height of a pedestrian. Right image: the refined research zone after adding some margins.

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Further considerations for multi-sensor fusion

- A unified representation model for obstacles.
- Spatial and temporal alignment.
- Data association.
- State estimation.

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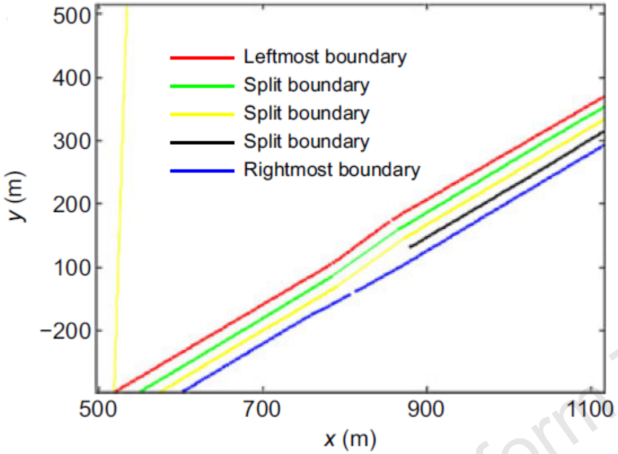
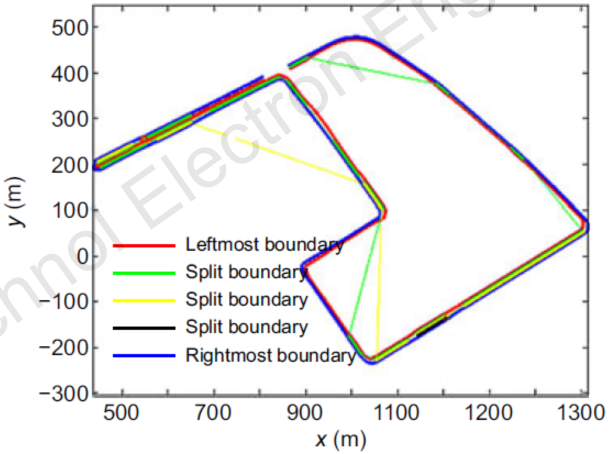
Experiments





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Multi-lane map generating by proposed algorithm in real traffic scene.

Experiments

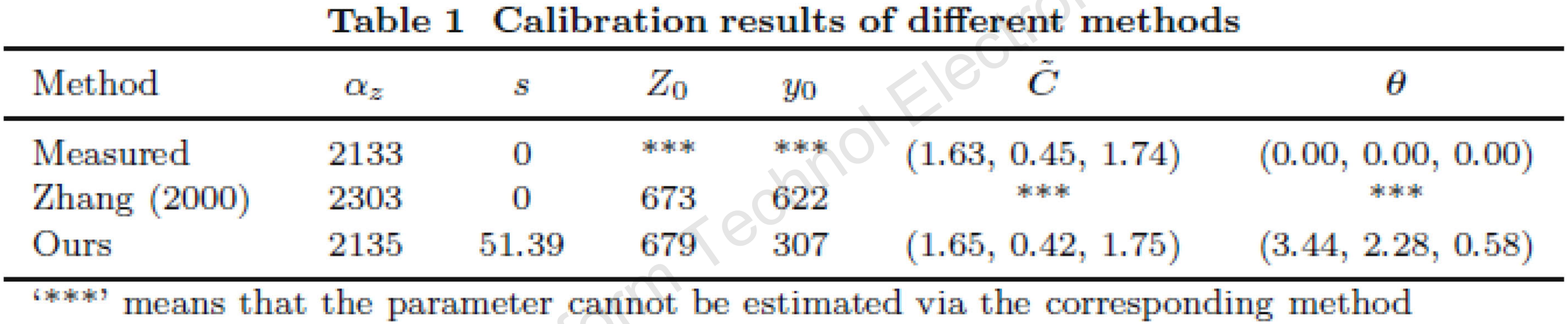

Table 1 Calibration results of different methods

Method	α_z	s	Z_0	y_0	$\tilde{C}$	θ
Measured	2133	0	***	***	(1.63, 0.45, 1.74)	(0.00, 0.00, 0.00)
Zhang (2000)	2303	0	673	622	***	***
Ours	2135	51.39	679	307	(1.65, 0.42, 1.75)	(3.44, 2.28, 0.58)

'***' means that the parameter cannot be estimated via the corresponding method

Our calibration results are almost as accurate as measured parameters.

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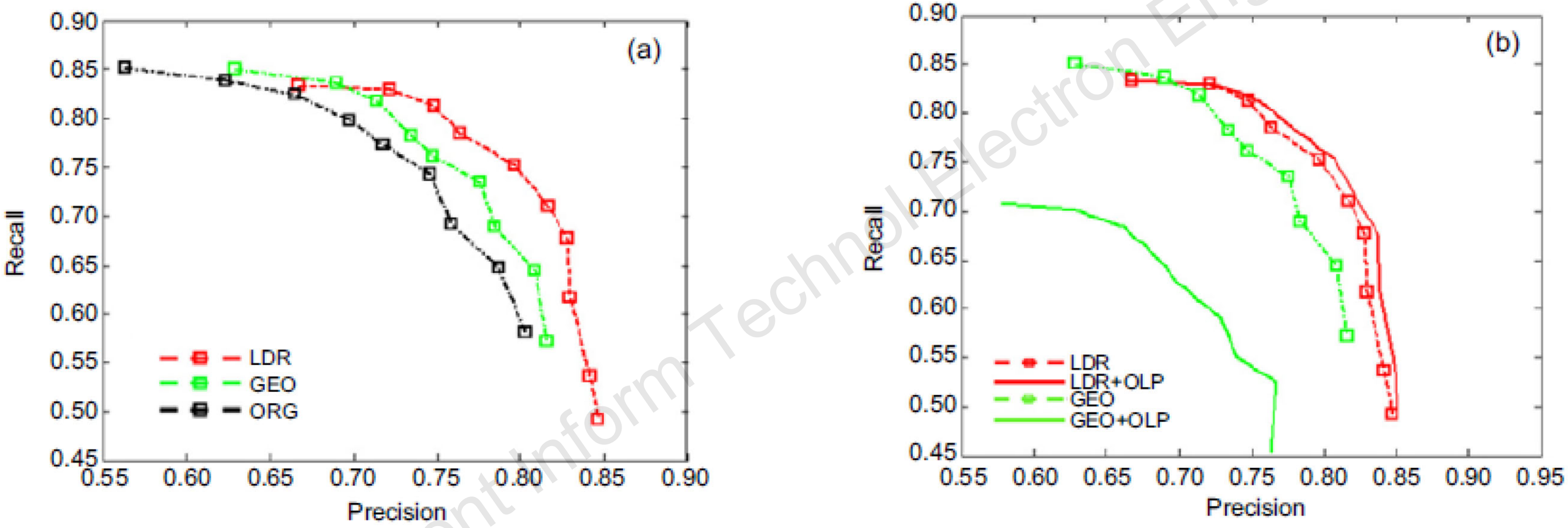
Experiments



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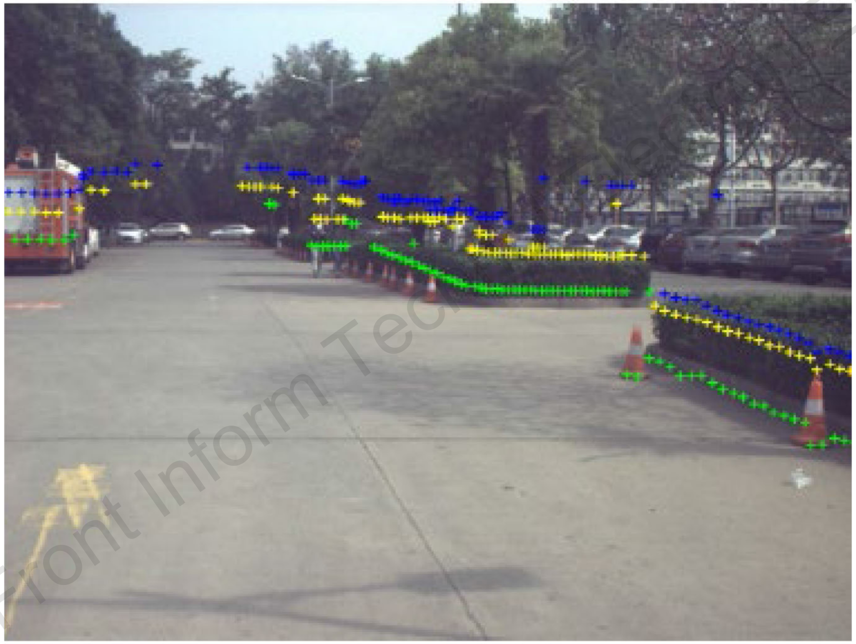
Precision-recall curves for various methods

Experiments



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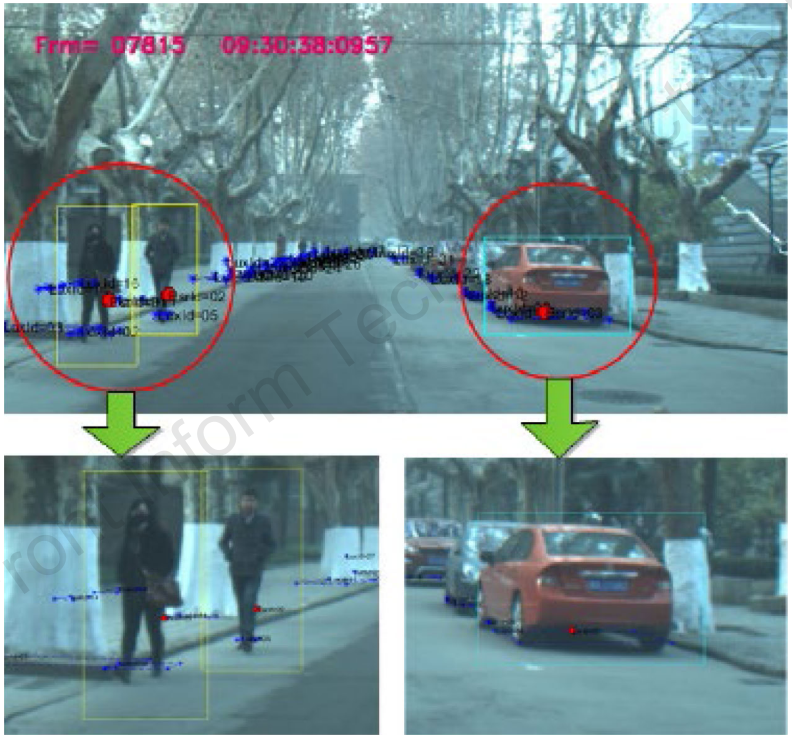
Failure case. The pedestrian is discarded incorrectly due to the road is uphill, which causes an incorrect mapping of LIDAR to the image.

Experiments



The effect of the multi-sensor fusion algorithm on a campus environment.

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Conclusions

- Machine vision algorithms are the core of the environment perception system, and propose algorithms including vision-centered mapping and localization, as well as vision-centered obstacles detection and recognition.
- the proposed vision-centered multi-sensor fusing method works well through a long term test based on the robotic car KUAFU-1 autonomously driving in various real urban traffic environments.

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