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

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.

Timeline of the robotic cars



Self-localization

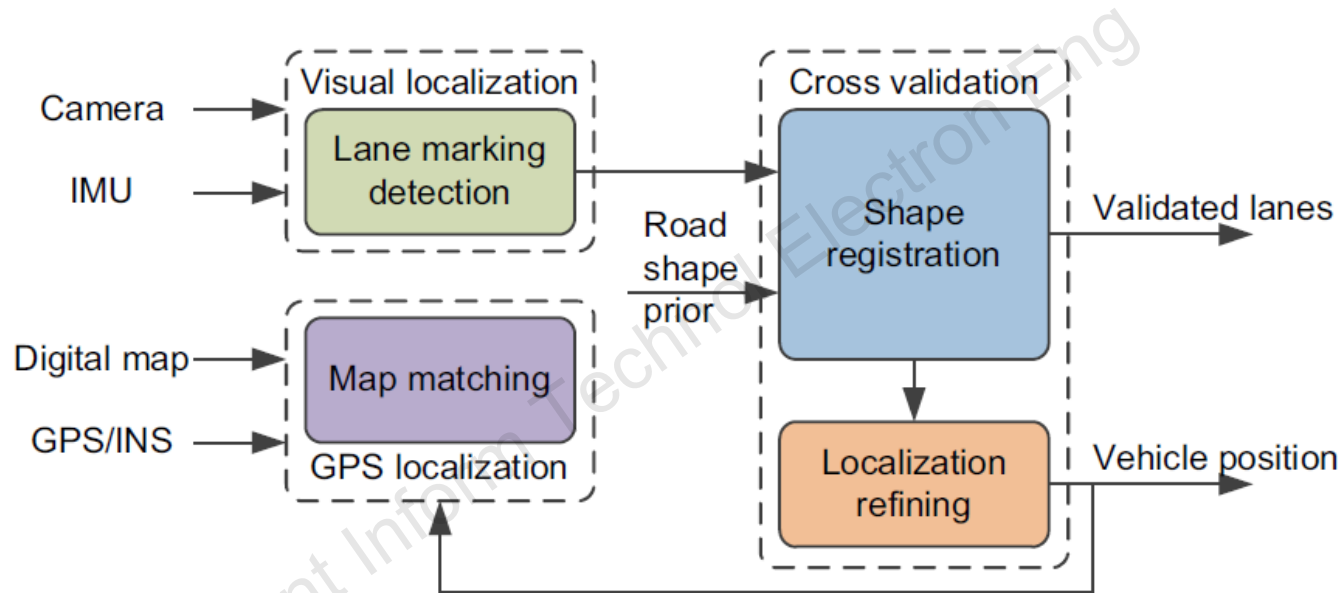


Fig. 2 Architecture of the proposed self-localization system

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.

Self-localization at the centimeter level

➤ Visual localization.

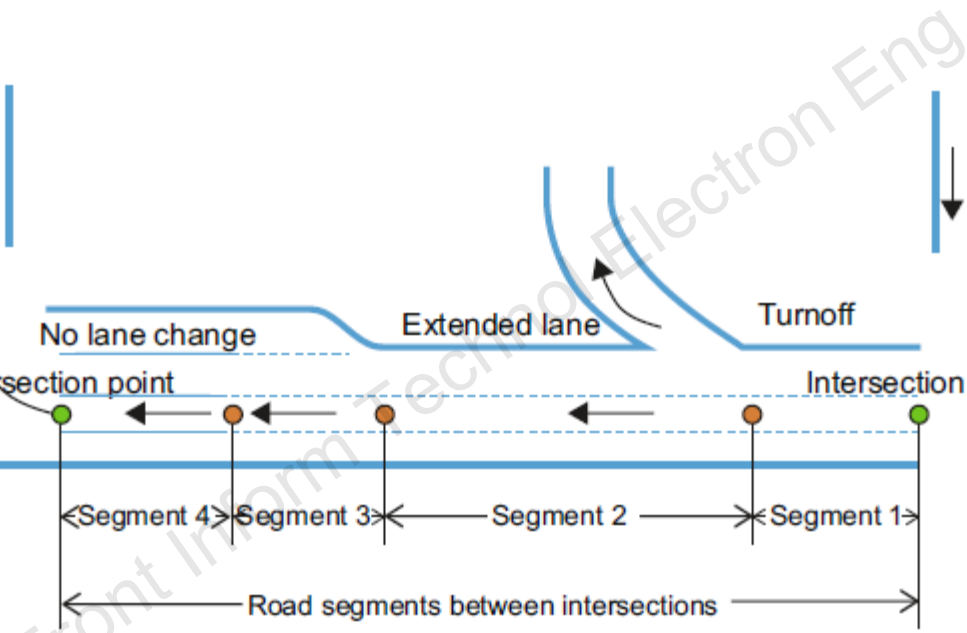
Integrating lane marking detection with the camera pose measurements from IMU.

➤ GPS localization.

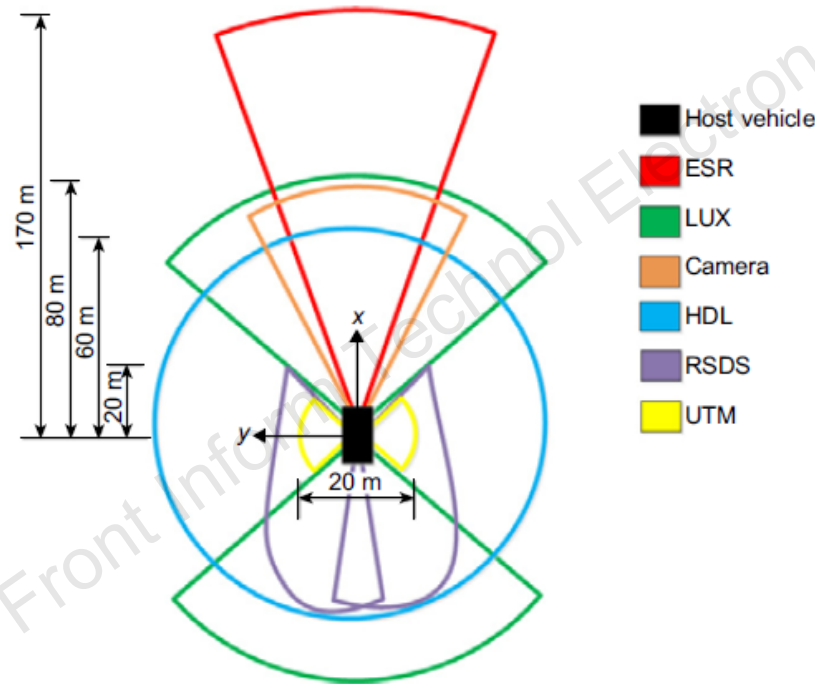
GPS position fixes are used as an initialization for map matching algorithm.

➤ Cross validation.

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



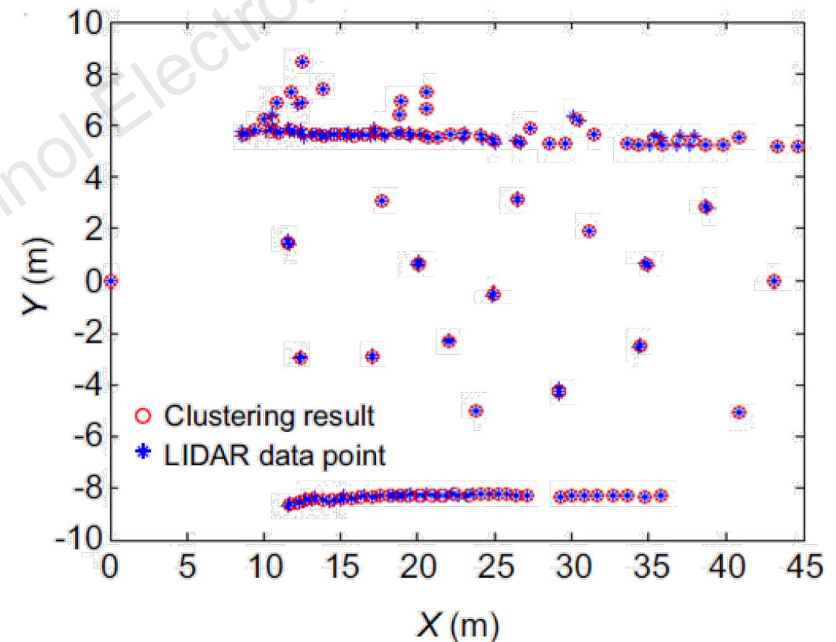
Multi-sensor fusing for obstacle detection and tracking



The sensor configuration for KUAFU-1

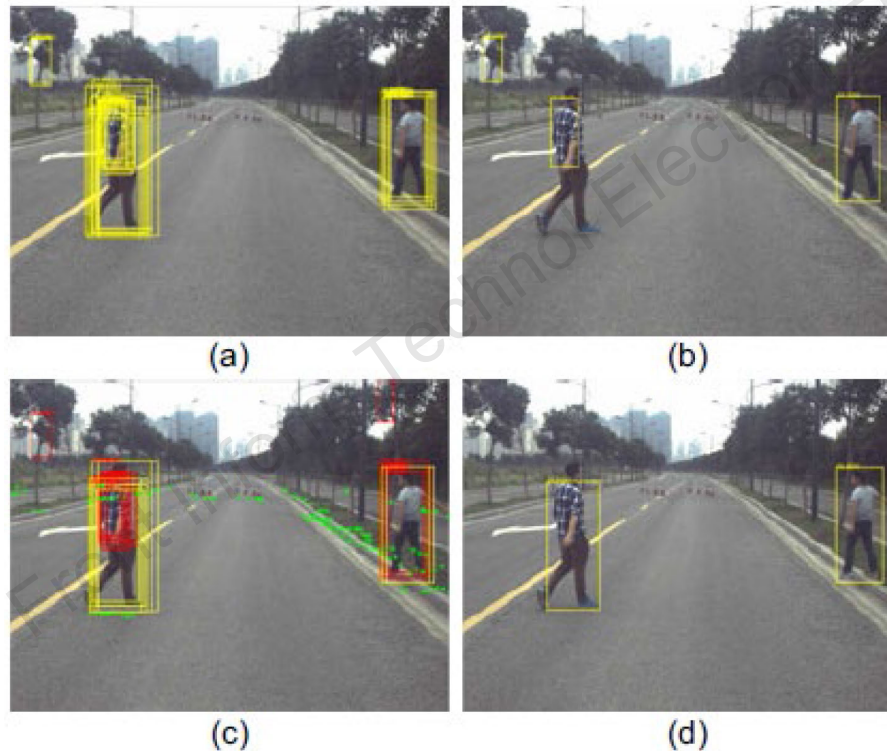
Calibration LIDAR with camera

Finding out a homography transformation.



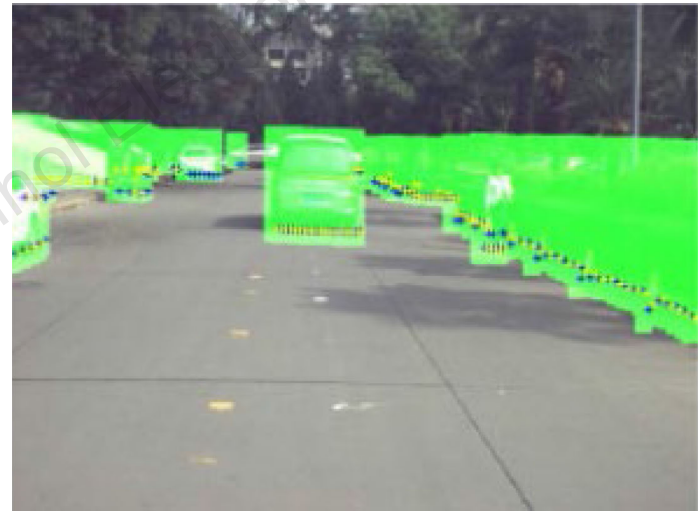
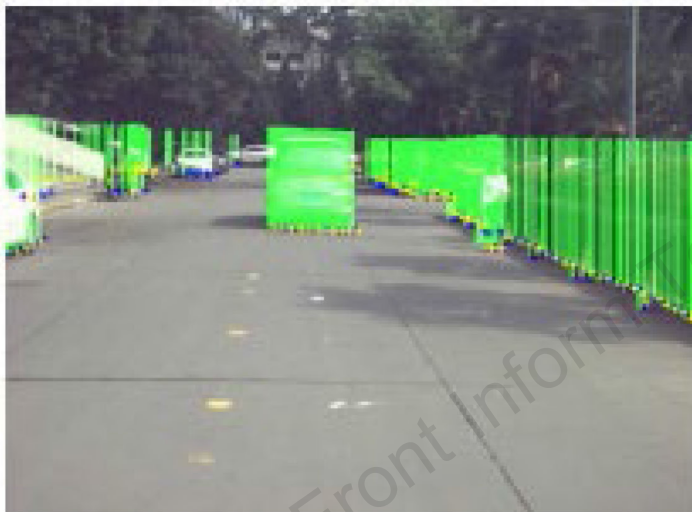
Traffic cones(upper and bottom side) are used for calibration LIDAR with camera.

Pedestrian Detection



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

Reducing the search region



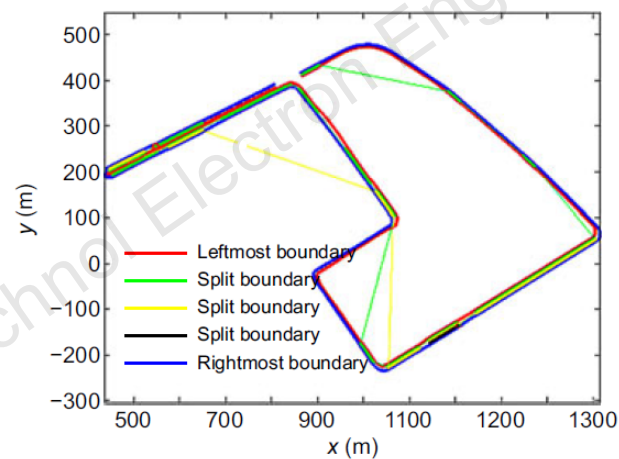
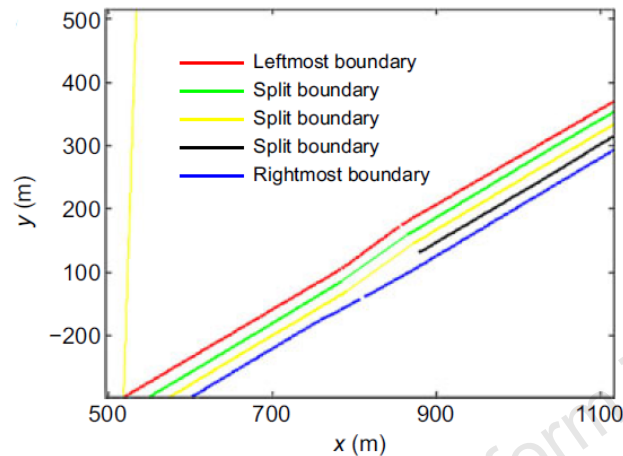
Left image: the LIDAR points are projected onto the image with a height of a pedestrian. Right image: the refined research zone after adding some margins.

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



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

Experiments

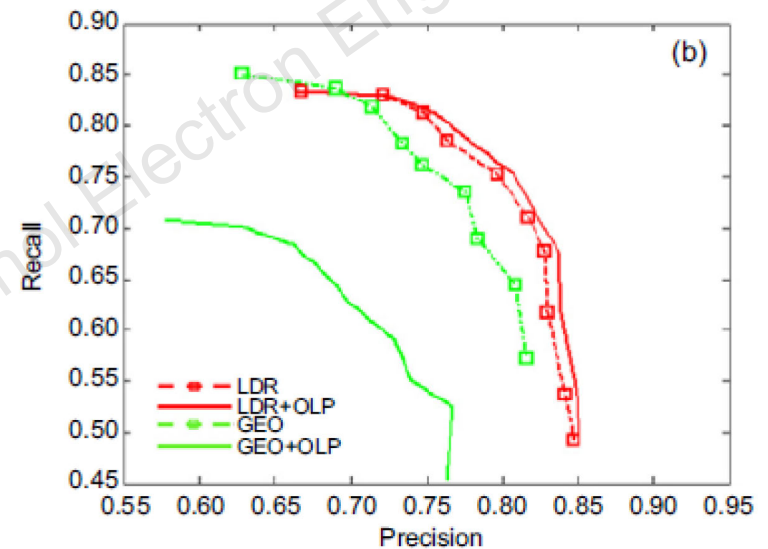
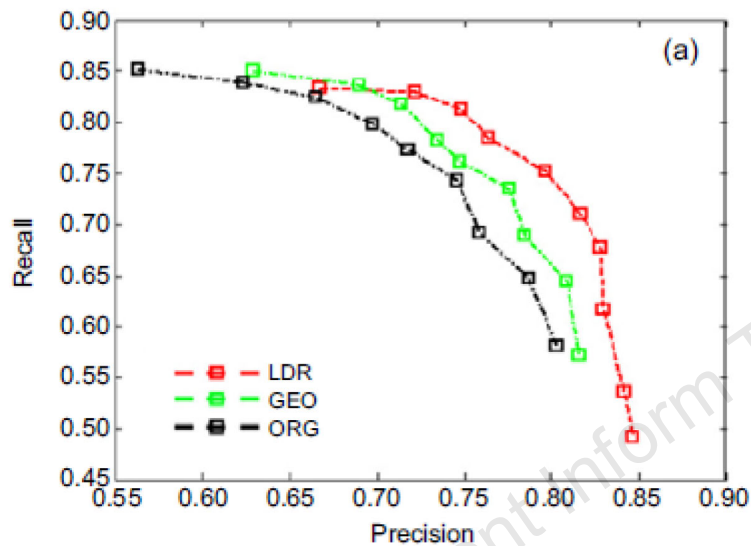
Table 1 Calibration results of different methods

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.

Experiments



Precision-recall curves for various methods

Experiments



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.

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.