Efficient Extrinsic Calibration System of a Camera and a 3D LiDAR with Accurate Feature Extraction and Error Diagnostics

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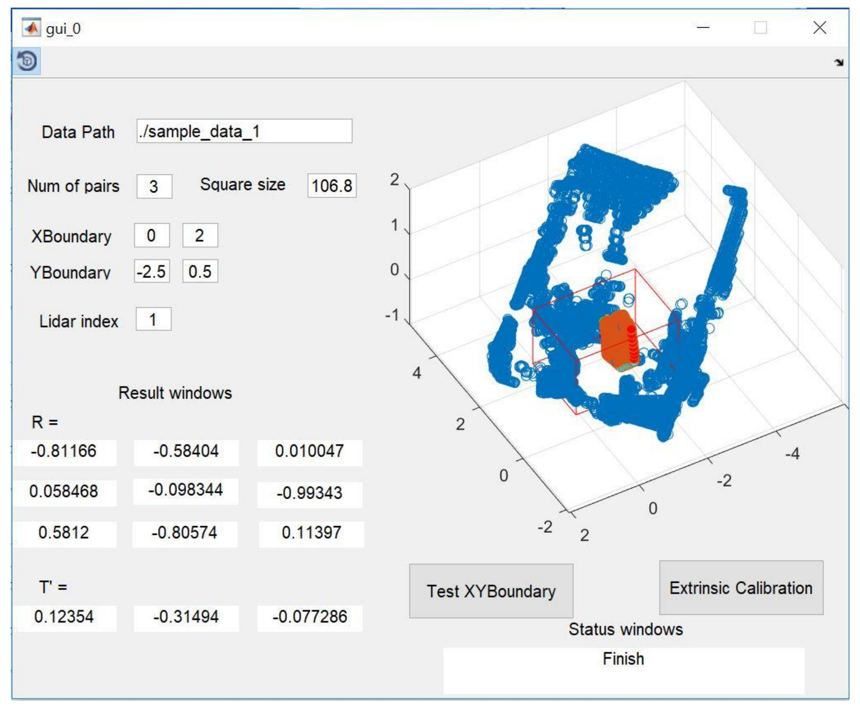
Objectives

1. ***Improve the accuracy of extrinsic calibration result in a camera and a 3D LiDAR.***
2. ***Strengthen the robustness and usability of an extrinsic calibration system.***

Introduction

1. *Motivation*

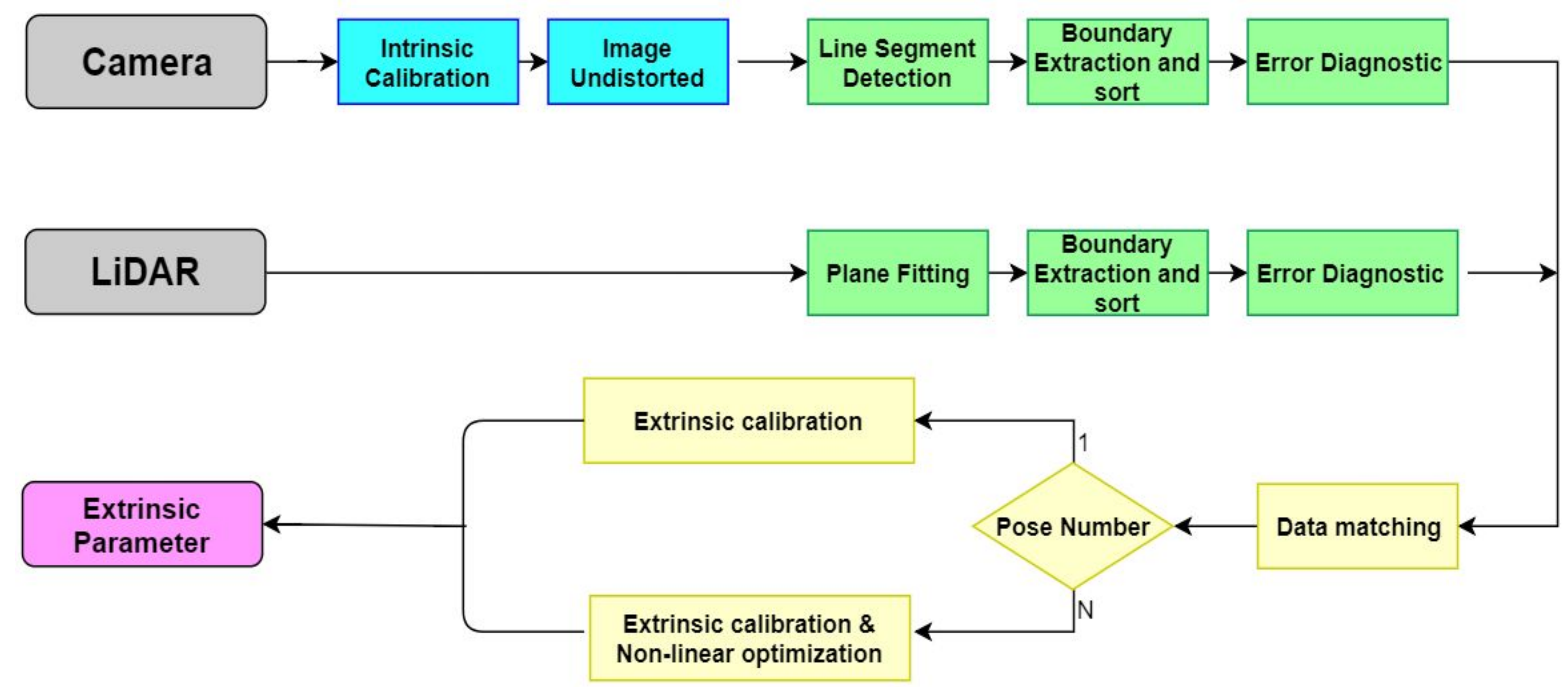
- In recent robotic research and applications, a camera and a 3D Light Detection and Ranging(LiDAR) sensor are often used together to collect environmental information. The color and texture of different objects could be easily captured through a camera. The deep depth information could be obtained by LiDAR.
- In order to effectively obtain and combine the information from both camera and 3D LiDAR, the accuracy extrinsic parameters, which include rotation and translation, between two sensors are required to obtain in advance.
- A robust and easy-to-used calibration system could reduce the time consumption in calibrating a large number of cameras and 3D LiDAR, which could benefit the utilization in large-scale industry.



2. *Contribution*

- Strengthen the usability through an efficient calibration toolbox with a user-friendly GUI, as shown above.
- Improve the accuracy of extrinsic calibration result in a camera and a 3D LiDAR by improving the precision of feature extraction.
- Strengthen the robustness of the extrinsic calibration system with an error diagnostics approach in extracted features.

System Description

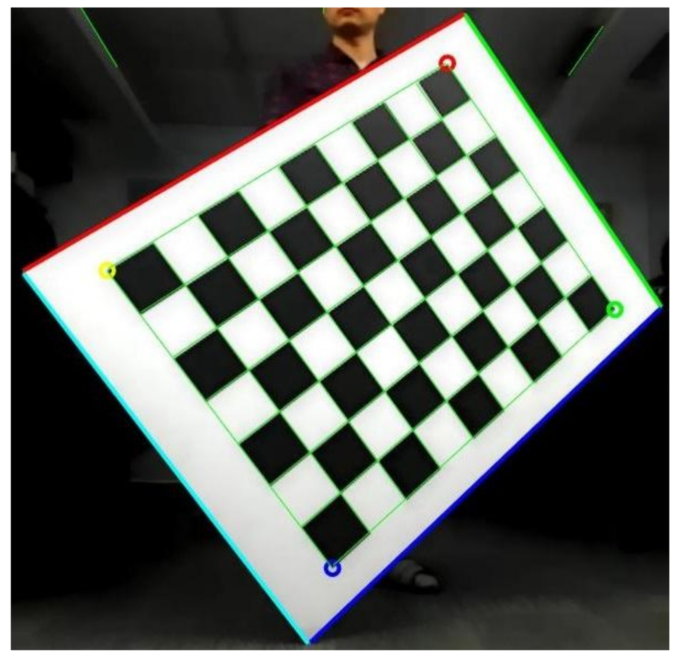


The extrinsic calibration system of a camera and a 3D LiDAR consist of 4 parts:

1. *Intrinsic calibration of camera to obtain distortion parameter for image recovery.*
2. *Extract the Boundary and plane of the checkerboard in camera and 3D LiDAR.*
3. *Conduct error diagnostic for extracted features in camera and 3D LiDAR.*
4. *Data matching and Extrinsic calibration.*

Feature Extraction and Error Diagnostics

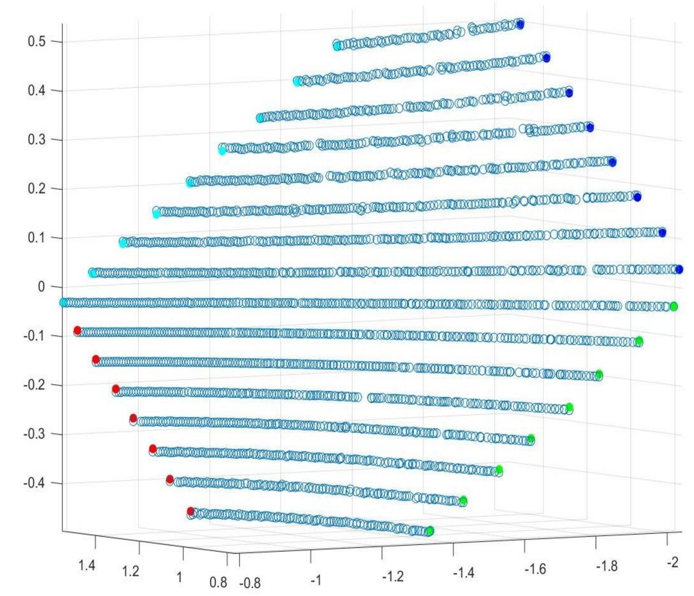
1. *In Image*



- Extract the lines in checkerboard by LSD [1] algorithm with improvement by Gaussian smoothing and line fusion.
- Diagnose the extracted boundaries by using line-to-line matching in image and the checkerboard with homographic transformation.

$$L_W = H^T \cdot L_I$$

2. *In Point Cloud*



- Fitting the plane of checkerboard and lines of the checkerboard boundaries in point cloud with RANSAC [2] algorithm.
- Diagnose the extracted lines by using perpendicular constraint of checkerboard boundaries

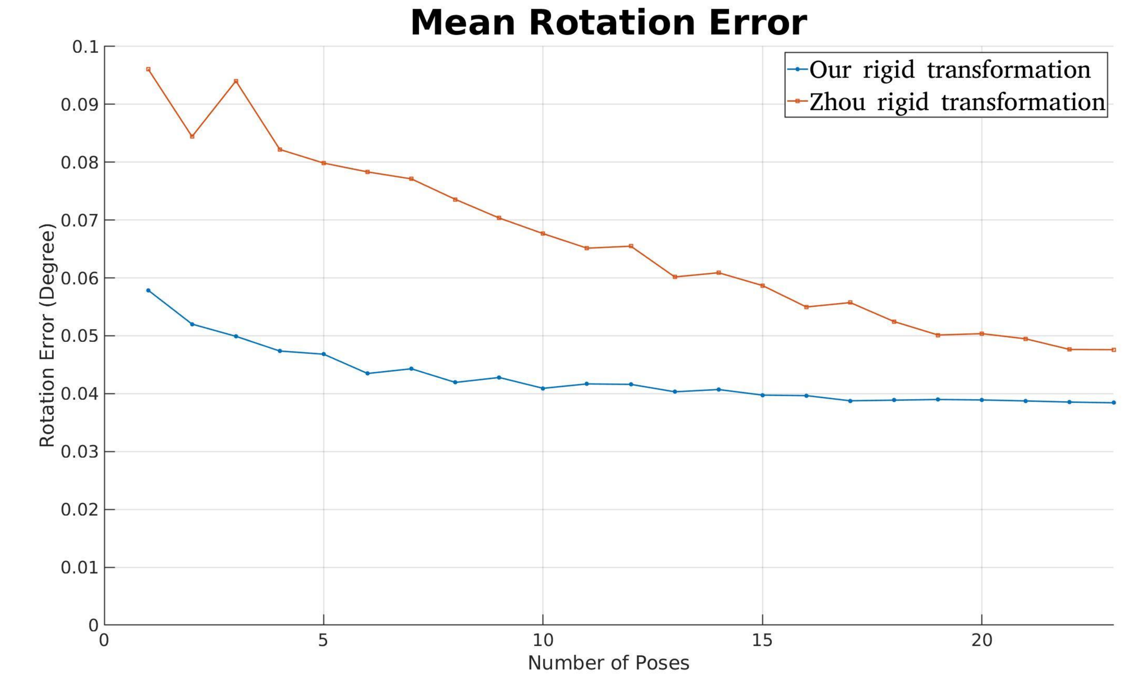
$$d_{ji} \cdot d_{ji+1} < \nu$$

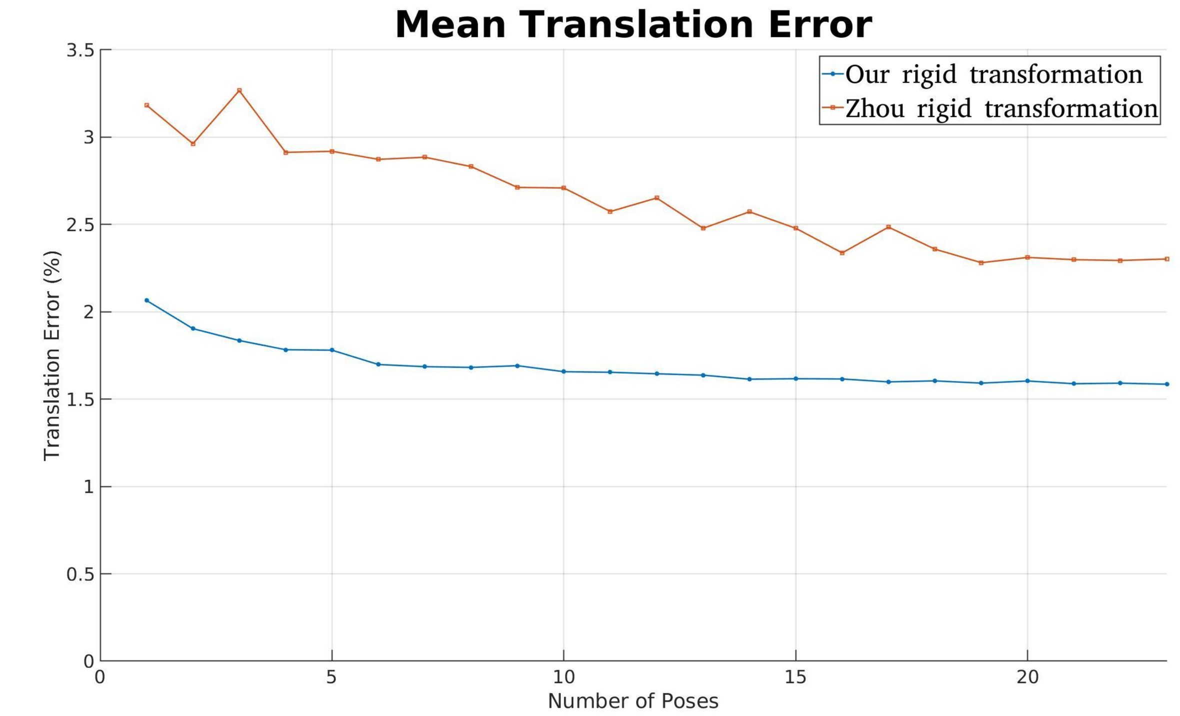
Experiment Validation

1. *Experiment*

- *Planform:*
  Velodyne VLP-16 LiDAR and a ZED stereo camera
- *Ground truth:*
  Extrinsic parameter of ZED stereo camera
- *Baseline:* Zhou's method [3]

2. *Result*





Reference

[1] R. Grompone von Gioi, J. Jakubowicz, J.-M. Morel, and G. Randall, "LSD: a Line Segment Detector," Image Processing On Line, vol. 2, pp. 35–55, 2012.
[2] M. A. Fischler and R. C. Bolles, "Random sample consensus: A paradigm for model fitting with applications to image analysis and automated cartography," Commun. ACM, vol. 24, no. 6, pp. 381–395, Jun. 1981. [Online]. Available: http://doi.acm.org/10.1145/358669.358692
[3] L. Zhou, Z. Li, and M. Kaess, "Automatic extrinsic calibration of a camera and a 3d lidar using line and plane correspondences," in Intel-ligent Robots and Systems, 2018. IROS 2018. IEEE/RSJ International Conference on. IEEE, 2018.

Future Work

1. Implement this extrinsic calibration system to a multi-sensor calibration system.
2. Implement this extrinsic calibration on an online localization and mapping system.

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