Continuous Target-free Extrinsic Calibration of a Multi-Sensor System from a Sequence of Static Viewpoints

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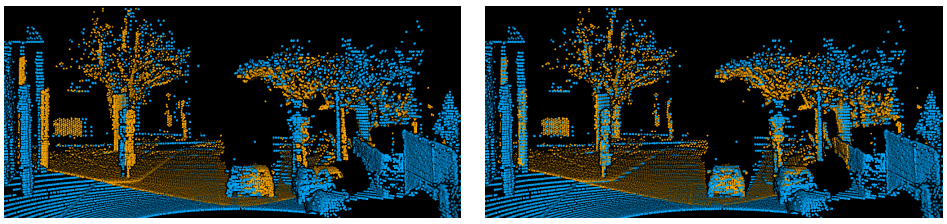
1 Introduction

Mobile robotic applications need precise information about the **geometric position of the individual sensors on the platform**. This information is given by the **extrinsic calibration parameters**. In this work we propose a new method for a **continuous estimation of the calibration parameters during operation of the robot**. The parameter estimation is based on the **matching of point clouds** which are acquired by the sensors from **multiple static viewpoints**. Consequently, our method **does not need any special calibration targets** and is applicable to any sensor whose measurements can be converted to point clouds.

Fig.1: Effect of an extrinsic calibration on the alignment of two lidar point clouds.



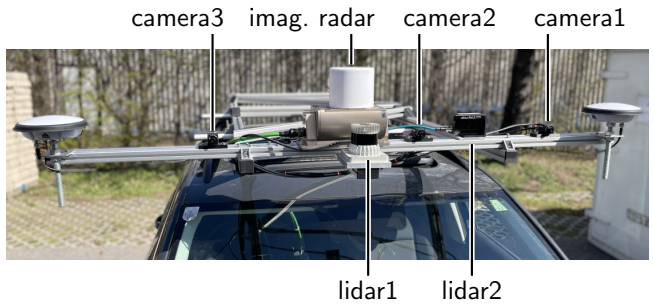
before calibration | after calibration

2 Novelty of our method

We propose in this work a **new online target-free calibration method**.
The main advantages in comparison to previous works are that:

1. the calibration is widely **sensor agnostic**, as it is applicable to any sensor whose measurements can be converted to point clouds
2. the **calibration parameter estimates are continuously improved during the operation of the robot** until a user-defined threshold is reached
3. **multiple sensors** can be calibrated at the same time.

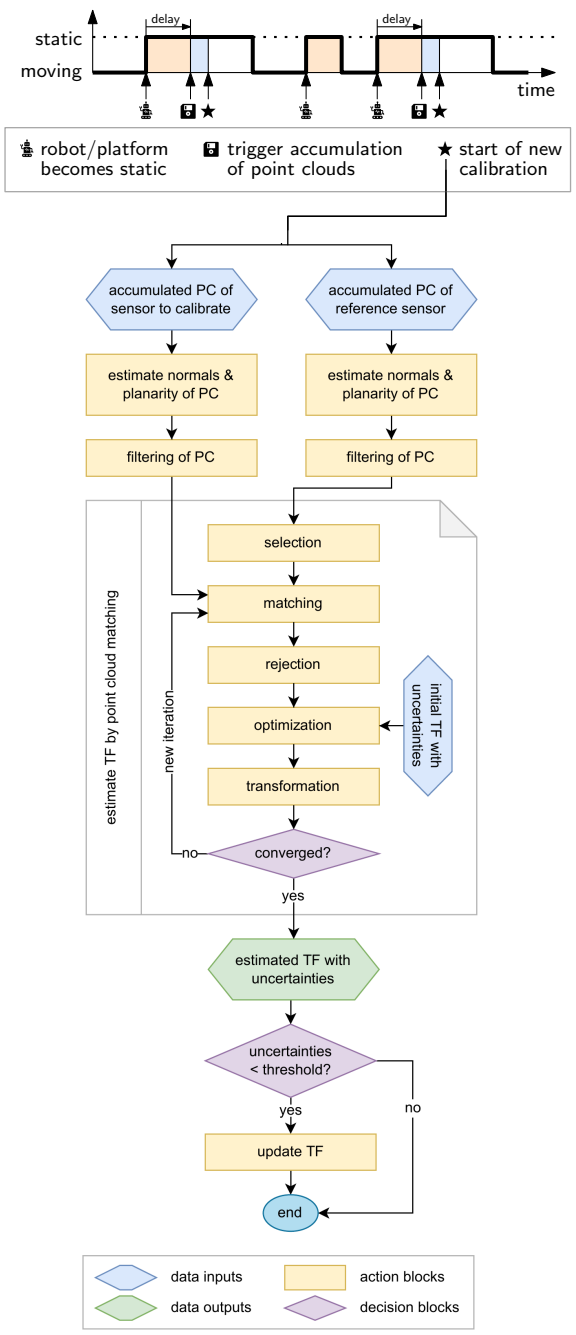
Fig.2: The proposed method can be applied to estimate e.g. the extrinsic calibrations for this sensor rig: 3 cameras, 2 lidars, and an imaging radar sensor.



3 Calibration method

The **temporal sequence of the calibration** is depicted in the figure below. We distinguish between a **static and a moving state of the robot**. Each time the robot becomes static, the **accumulation of point clouds** is triggered after a certain time delay (e.g. 2 seconds). As soon as the accumulation of point clouds is completed, a **new calibration is started**. This sequence is repeated until the estimated calibration parameters are sufficiently accurate.

Fig.3: Temporal sequence of the calibration (top) and processing workflow of a single calibration (bottom).



Experimental results

The proposed calibration method was applied to estimate the extrinsic calibration of the sensors depicted in Fig. 2. The point clouds provided by these sensors are visualized for a single calibration site in Fig. 5. The sensors have been calibrated during an **8 minute drive** (Fig. 4). In this time period, the car stopped 12 times. Accordingly, the calibration was triggered at **12 different calibration sites**.

Fig.4: The multi-sensor system depicted in Fig. 2 was calibrated during an 8 minute drive at 12 calibration sites.

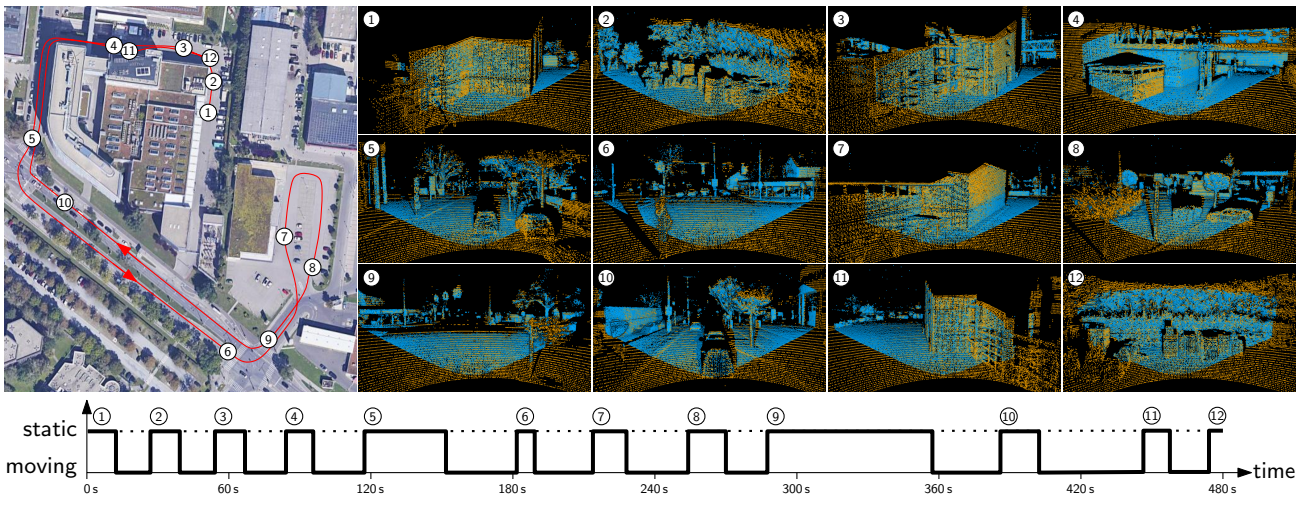


Fig.5: Data belonging to calibration site 7. First row: point cloud of the reference sensor lidar1 and a corresponding image of the site. Rows 2–4: point clouds of the sensors to calibrate (left) and histograms of the residual point-to-plane distances (right).

Fig.6: Temporal development of some calibration quality indicators for the sensor combination lidar1-to-lidar2, c.f. Fig. 2.

4 Outlook

Our future work will concentrate on:

- the **automatic removal of dynamic objects** (like cars, persons, etc.) from the collected point clouds
- the **calibration of sensors which provide 2D point clouds only**, i.e. a profile of the environment
- better **understand the long-time behavior of the estimated precision of the calibration parameters**, e.g. for an operation time of several hours

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