**Self-Calibration for LiDAR-based Mobile Mapping Systems**

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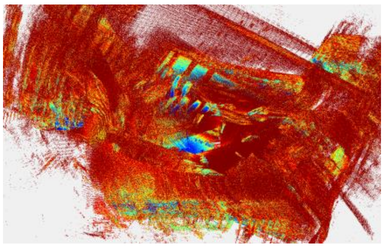
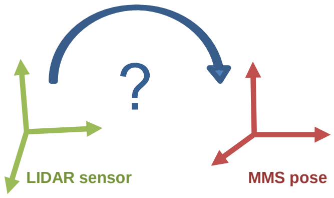

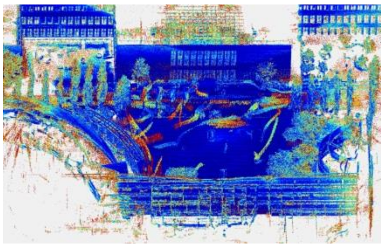

Mobile Mapping is an efficient technology to acquire spatial data of the environment. The spatial data can be further processed to 3D city models, building models or models of indoor environments which are nowadays an essential data source for applications in crisis management, civil engineering or autonomous driving. Depending on the scale of the environment, mobile platforms like airplanes, cars, Unmanned Aerial Vehicles (UAVs) or mapping backpacks are considered. The mobile platform is typically equipped with one or more mapping sensors. In this regard, a widely utilized mapping sensor is a laser scanner, also known as Light Detection And Ranging (LiDAR) sensor, since it acquires accurate and dense spatial data of the environment in the form of a 3D point cloud.

The quality of a 3D point cloud captured with a Mobile Mapping System (MMS) is limited by the accuracy of the laser scanner itself and mainly three more components: The estimation of the *pose* of the MMS, the *intrinsic calibration* of the individual sensors (e.g. LiDAR sensors or/and cameras) and the *extrinsic calibration* of the MMS.

- The *pose* describes the position and orientation of the MMS with respect to a superordinate coordinate frame. It is used to register a single scan to a common point cloud. The pose is estimated in a specific frame which we call the navigation frame. The pose estimation task can be solved by using a technology that observes the sensor system, like for example the Global Navigation Satellite System (GNSS), or by using on-board sensors and an odometry- or Simultaneous Localization and Mapping (SLAM)-algorithm.
- The *intrinsic calibration* is the process of estimating the interior calibration parameters of the individual sensors. In case of a laser scanner, these are for example a range finder offset and beam direction influences. As the impact of the interior calibration parameters on the accuracy of the point cloud is typically lower than the impact of the other mentioned components, the interior calibration parameters of mapping sensors are often neglected. However, for highest accuracy requirements, the interior calibration parameters must be taken into account.
- The objective of the *extrinsic calibration* of a MMS is to find a rigid transformation from the navigation frame to the frame of the mapping sensor.

In general, the calibration approaches can be arranged into three categories: (i) Calibration approaches which are performed in the laboratory, (ii) calibration approaches which use specific, artificial targets and (iii) self-calibrations. Self-calibrations are the most practical and time-saving approaches, as it is possible to calibrate the system based on the data that shall be collected anyways. There is no need to prepare the environment before data collection, to design artificial targets or to use additional sensors in self-calibration processes. The fundamental assumption of the self-calibration is that the calibration parameters are estimated the best when the derived point cloud represents the real physical circumstances the best. Moreover, self-calibrations can be more accurate because changes of the calibration parameters during data collection can be taken into account. In this presentation, the idea of a self-calibration approach which is based on geometric features [1,2] is depicted.

Geometric features are often used to automatically analyze 3D point clouds. The most popular task in this context is classification, but geometric features have also been used for coarsely registering 3D point clouds and retrieving objects in 3D point clouds. Particularly, the geometric features derived from eigenvalues of the 3D structure tensor have proven to be descriptive. As these features represent a specific property of the local neighborhood by a single value, they are rather intuitive. The three features of linearity, planarity and sphericity, for example, allow to quickly identify the primary dimensionality within a local neighborhood. Therefore such geometric features can be used to evaluate the quality of a point cloud and thus to evaluate the calibration of a MMS with a laser scanner and a pose estimation sensor.

In this presentation, a novel extrinsic self-calibration approach for Mobile Mapping Systems is introduced. It will be shown that the self-calibration is able to extrinsically calibrate Mobile Mapping Systems with different combinations of mapping and pose estimation sensors such as a 2D laser scanner to a Motion Capture System and a 3D laser scanner to a stereo camera and ORB-SLAM2. Further, for autodidactic purpose, the MATLAB Code *FeatCalibr* of our self-calibration framework can be accessed [3]. This self-calibration approach combines all of the following advantages simultaneously: (i) the estimation of all extrinsic calibration parameters between an arbitrary pose estimation sensor and a mapping sensor, (ii) a universal solution suitable for different kinds of mapping sensors (e.g., 2D and 3D laser scanners), (iii) no assumptions about the environment and no requirements for artificial targets or additional sensors, and (iv) a solution robust to initial calibration errors due to a multi-scale approach.

References


[1] Hillemann, M.; Meidow, J.; Jutzi, B. (2019). Impact of different trajectories on extrinsic self-calibration for vehicle-based mobile laser scanning systems. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-2/W16, 119–125. doi:10.5194/isprs-archives-XLII-2-W16-119-2019

[2] Hillemann, M.; Weinmann, M.; Mueller, M. S.; Jutzi, B. (2019). Automatic Extrinsic Self-Calibration of Mobile Mapping Systems Based on Geometric 3D Features. *Remote Sensing*, 11 (16), Article: 1955. doi:10.3390/rs11161955

[3] MATLAB Code *FeatCalibr*: https://github.com/markushillemann/FeatCalibr