Synchronization aspects of sensor and data fusion in a research multi-sensor-system

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Abstract: This contribution deals with a research multi-sensor-system (RMSS) to investigate the crucial point of sensor synchronization. The common stable time frame is realized by a GPS/Raspberry Pi stratum 0 time sever. To show the capabilities of the RMSS the resulting 3D point cloud is compared with 3D point clouds obtained by classical terrestrial laser scanning.

1 INTRODUCTION

The research multi-sensor-system (RMSS) aims to investigate the crucial point of sensor synchronization. The RMSS is a small-scale vehicle driving autonomously on a rail in an indoor laboratory. As core processing and data storage unit is utilized a single-board computer of type Raspberry Pi Model B running Ubuntu 14.04 LTS (Trusty Tahr). The RMSS is accelerated by means of a stepper motor. Its trajectory is observed by means of an inertial measurement unit (IMU) of type TinkerForge IMU Brick 2.0 and a two-axis inclinometer. To obtain absolute position information the RMSS is equipped with prisms which are tracked by a robotic total station or a laser tracker. Aforementioned sensors form the group of referencing sensors. Besides this, the RMSS is equipped with object capturing sensors, like a profile laser scanner of type Hokuyo UST-10LX and a Raspberry Pi camera module with wide-angle-lens. The control of the sensors as well as their data acquisition is performed by the Robot Operating System (ROS), Version Jade.

The establishment of a common stable time frame for all sensors is the initial step in the synchronization process within the RMSS. The common stable time frame is realized by the network time protocol (NTP) while the Raspberry Pi is used as a stratum 0 time server using either time transmission via radio communication (DCF77) or the GPS time.

The mutual position and orientation of the enlisted sensors in the RMSS are obtained within a system calibration approach. The final data fusion of the referencing sensors is realized by a Kalman Filter approach. Afterwards it is possible to build up a 3D point cloud out of the profile laser scanners' measurements.

2 METHODS

This methods section will focus on the performed system calibration of the RMSS. The establishment of the common stable time frame is currently under development and will be presented in detail in the paper.

The first step is the definition of the RMSS coordinate frame, also called body frame. Afterwards each individual sensor, with its sensor frame, has to be transformed into the body frame by up to six degrees of freedom (dof). A superior navigation frame is realized by the external tracking measurements.

To highlight one of the dof determination, it is focused on the procedure for obtaining the six dof for the laser scanner. The required six dof (three translations and three rotations) are determined according to the proposed approach by Strübing and Neumann (2013). The authors utilize a sensor of superior accuracy with respect to the laser scanner in use. Due to the manufacturer provided uncertainty of 40 mm absolute and 30 mm repeatability (Hokuyo, 2015) a standard tacheometer is well suited. This sensor of superior accuracy, here a tacheometer, acquires point-wise data of a set of reference geometries, here planes. The plane parameters are obtained within an adjustment approach. In addition, control points of the body frame are measured to immediately transform all tacheometer measurements into the body frame. Subsequently, the plane-based reference geometry is captured by the laser scanner firmly attached in the non-moving RMSS. Finally, the six dof are estimated in a Gauß-Helmert model (GHM) by minimizing the distances of the laser scanner observations of the planes with respect to the planes estimated by means of the tacheometers' measurements. For details of the adjustment approach see Diener et al. (2016), Hartmann et al. (2015) as well as Strübing and Neumann (2013).

3 RESULTS

In the following some selected results for the six dof determination of the laser scanner are presented. In Figure 1, the residual vector with values in the range of +/- 20 mm after the GHM adjustment is shown. The uncertainties for the translation parameters result to 0.3 mm and for the rotation parameters the uncertainties are ranging from 0.02 to 0.07 degrees.

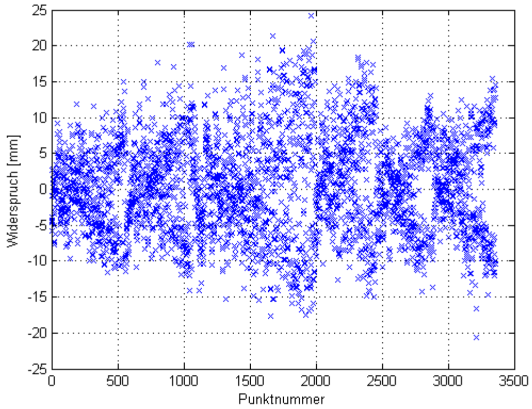

Figure 1: Residual vector of the GHM adjustment. Right: Resulting 3D point cloud colored in intensity.

Figure 2 shows the resulting 3D point cloud of the RMSS in the laboratory environment.

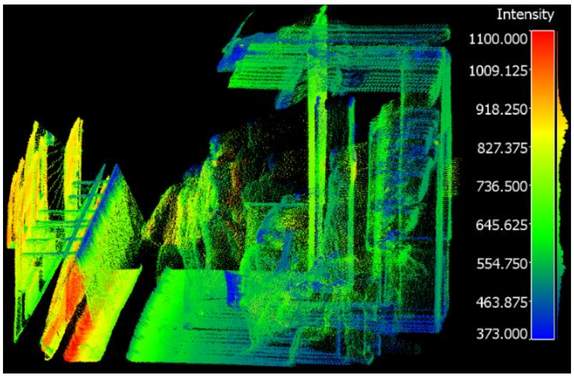

Figure 2: Resulting 3D point cloud colored in intensity.

4 CONCLUSIONS

To conclude this contribution it can be stated, that the recent realization of the RMSS is already suitable to acquire 3D point clouds of its environment with centimeter level of uncertainty due to the laser scanners' noise level. At the moment the speed of the RMSS is assumed to be constant in the calculation of the 3D point cloud. This assumption is error-prone which can be shown by the external tracking data. Current further developments aim to overcome this basic constant speed assumption by intensively using tracking and IMU data as well as an improved synchronization.

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