Preliminary Results on Instantaneous UAV-Based 3D Mapping for Rescue Applications

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Abstract— **This report presents a novel approach to generate a 3D map with an UAV while flying over a disaster scene with the aim to present the map instantaneously to the operator and the rescue workers. Our approach extends the well-known ICP algorithm.**

I. Introduction

The prompt availability of 3D maps in rescue applications is beneficial for many aspects, e.g., improved strategic planning for coordination, enhanced situation awareness for firefighters and rescue workers, structural inspection etc. All these aspects require instantaneous 3D mapping. Nowadays in typical small to medium sized missions the scene is inspected by humans or by video and still images (either color (RGB) or thermal) provided by a helicopter. Small rotocraft unmanned aerial vehicle (UAVs) are increasingly used for this purpose too, as they are more flexible and provide a higher level of availability. However the officers in charge have to manually control the UAV, inspect and sort the information to assess the situation.

In the project Eins3D (*Luftbasierte Einsatzumgebungsaufklärung in 3D*) we aim at developing a 3D mapping solution, that uses a small UAV for providing 3D maps in an instant fashion, a.k.a. real-time. Photogrametric approaches to 3D mapping do not provide 3D maps immediately [1] as dense mapping has high computational requirements. In the TRADR (Long-Term Human-Robot Teaming for Disaster Response) project 3D point clouds are generated from camera images –this time-consuming step needs often several hours– and combined with 3D point clouds laser scanners carried by ground robots [2]. Only the 3D point clouds of the ground robots are usually available in real-time.

The recent developments of lightweight laser scanners enable UAV-based 3D mapping and provide 3D data in real time. This paper gives an overview of the methods that are used to turn the sensor measurements into precise 3D point clouds.

II. System Overview

The main sensor of our UAV mapping system (Fig. 1) is a Velodyne VLP16 Lite laser scanner. It provides scans at a frequency of 10 Hz with a maximum range of 100 m It is mounted with a pitch angle of 45 $^\circ$ to increase the covered area on the ground. This oblique configuration has the advantage, that mapping of structures that can not be overflown is possible, e.g., houses on fire.

For positioning and localization we mounted an XSens Mti-G 700. This sensor fuses IMU and GPS data to increase the longterm stability of the orientation measurements and provides position data with 400 Hz. Additional sensors are mountable on the system. Currently an Optris PI400 Lightweight is used to provide registered thermal information. Data logging is done by a single board computer running ROS. The final system will be equipped with a wireless communication module to stream the sensor data to the ground station.

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III. Instantaneous Mapping

A. Initial Pose Estimation

Although the Xsens Mti-G 700 provides filtered data, it turned out that the position information is not continuous. To deal with this problem we run an additional EKF to fuse velocity and position, to get a smooth trajectory.

A second issue was the timing between the IMU and the laser scanner. As the Xsens is connected via USB it suffers from delays. We applied the method of [3]. Assuming an online data stream we only used forward synchronization.

B. Point Cloud Optimization

The previously computed initial trajectory is then used to "unwind" the data of the Velodyne scanner. As the laser scans delivered by the VLP16 are sparse in the vertical direction, registration with the common iterative closest point (ICP) approaches on two consecutive scans will fail. Zhang and Singh address this problem of sparseness by detecting edge points and planar patches [4]. Holz and Behnke estimate the underlying surface and use a variant of the general ICP to register point clouds with inhomogeneous density [5].

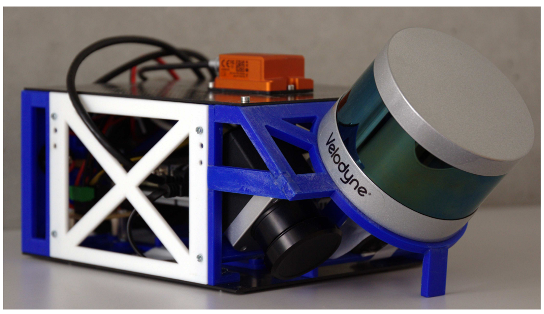

Fig. 1: Prototype of the mapping module.

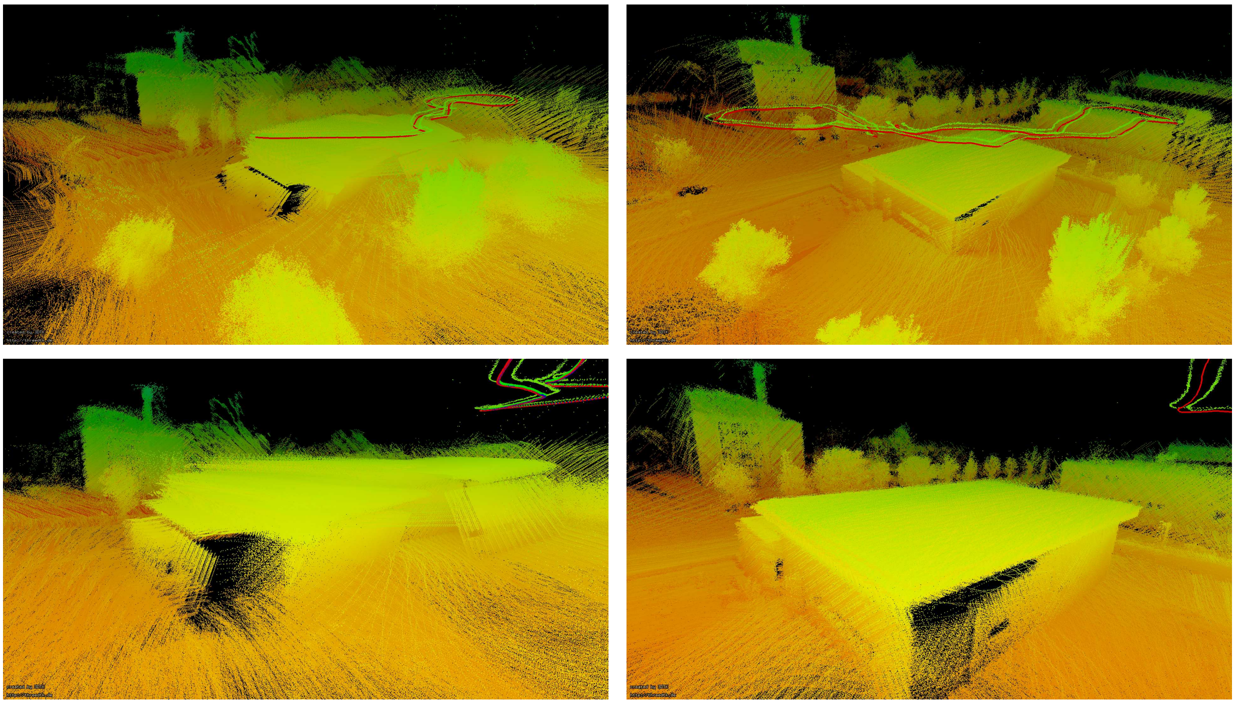

Fig. 2: Left: 3D point cloud with initial trajectory estimation. Note, that the highest position error is in the up axis. Right: Point cloud after applying semi rigid ICP with loop closing.

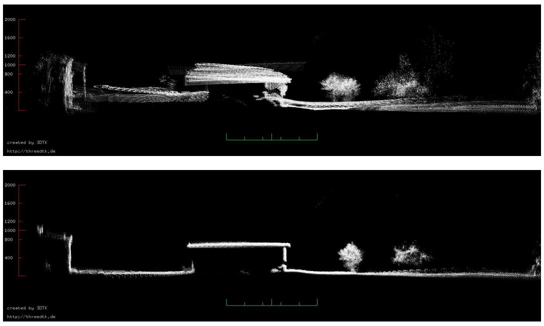

Fig. 3: Cross section of the initial (top) and the optimized (bottom) point cloud.

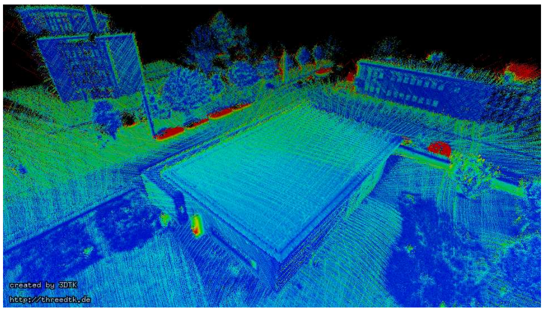

Fig. 4: Cloud to cloud error. Red indicates high errors, blue low errors.

Our approach extends the work in [6]. Using the trajectory we group several consecutive scans to so-called meta-scans to get dense point clouds which are registered rigidly. To ensure a continuous trajectory we distribute afterwards the transformation of the meta-scans to the single scans. This resembles a semi-rigid ICP algorithm, which can also be called continuous-time ICP [7].

IV. Experiments and Preliminary Results

The mapping system was tested on a dji S900 UAV flown manually in several loops alongside the robotics hall of the university. The initial point cloud is shown in Fig. 2, left. The highest error appears to be in the up-axis, as the height estimation by barometer and GPS position is less precise. This is noticeable on the roof of the robotics hall as multiple layers. The second most prominent error is in the heading estimation, visible in the multiple appearance of the buildings in the background. In addition to applying the above described method, we used loop-closing. By applying our methods, the errors are corrected, cf. Fig. 2, right. Fig. 3 and 4 also visualize the improvements on the point cloud. Fig. 3 shows a cross section through the scene and Fig. 4 visualizes the deviation to ground truth.

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