Real time mapping from 3D sensor data using a Velodyne HDL-32E laser scanner*

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1 Introduction

In this work we propose a solution that employs the robot operating system (ROS) to design and implement a system for real time mapping of a robots local environment. Ego-centered elevation maps are calculated using the accumulated three dimensional sensor data of a state-of-the-art Velodyne HDL-32E laser sensor. The developed system is part of a safe semi-autonomous convoying demonstrator. The main contribution consists in a point cloud filtering method that reduced the computation time to achieve real-time mapping capability of the system. Related work can be found in [2], where a Velodyne HDL-64 is used to generate a global three dimensional map of the environment. Less expensive tilt-and-pan laser range finder are used like in [3], where a global elevation map is built from 3D data.

2 Mapping from 3D sensor data

We improved the existing velodyne driver stack of ROS and added an enhanced preprocessing and filtering. The data processing is separated into Preprocessing, pairwise registration, 3D-model update and elevation map calculation. The preprocessing encompasses the filtering of the sensor data and surface normals calculation. The surface normals are calculated by averaging the normal vectors of the triangles formed by the examined point and its neighbours. The first filtering stage is performed straight during the normal calculation process using the determined vectors necessary for normal calculation. Based on the distribution of the local point to neighbour distances of the examined point - which is assumed Gaussian - sparse outliers are removed. The point cloud data is further reduced by a segmentation based filter in the second filtering stage. It estimates and separates the ground plane using the surface normals. The separated datasets are voxel-grid-filtered with different voxel sizes and joined again for registration. To align a new laser dataset with the previous one the six DOFs of motion are computed with an ICP Algorithm. Given the scene characteristics, the point-to-plane error metric is used in order to allow sliding planes like the floors against each other [1]. The last 32 aligned measurements are accumulated in a local

* The project has been funded by the Austrian Security Research Program KIRAS an initiative of the Austrian Federal Ministry for Transport, Innovation and Technology (bmvit).

ego-centred 3D-model, which is updated with each new scan. It is then used to calculate the elevation map of the robots local environment. All cells of the elevation map are calculated with a Kalman Filter according to [3].

3 Results and Summary

Table 1 summarizes the performance improvements achieved by the added filtering methods. Due to the lack of any kind of ground truth motion data, we constructed an artificial loop $(S_1, S_2, ...S_{n-1}, S_n, S_{n-1}, ..., S_1)$ from n scans $(S_1, S_2, ...S_n)$ and compare the translational error $\|\boldsymbol{t}\|$ between start and end scan after registration. Figure 1 shows plots of the trajectories achieved using 295 unfiltered and filtered real-world scans with a total loop length of 165 m.

Table 1. Average computation times on a typical outdoor-scene

Dataset	Avg points per scan	Registration	Model update	Map Calculation	$\|\boldsymbol{t}\|$
Unfiltered	41487	1320,80 ms	1060,90 ms	435,79 ms	1,024 m
Filtered	3399	213,89 ms	152,90 ms	32,25 ms	1,406 m

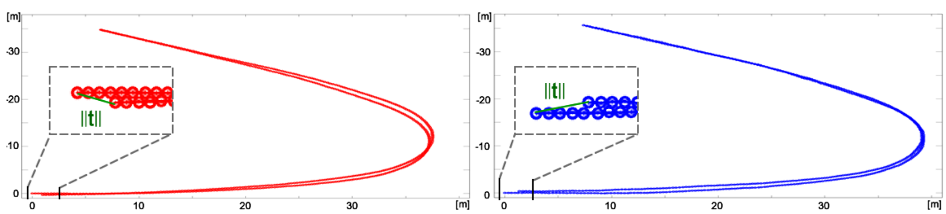

Fig. 1. Resulting trajectories from unfiltered (left) and filtered (right) point clouds

We presented a software system to calculate ego-centered elevation maps of a robots local environment out of 3D sensor data using the ROS framework. Applying the newly implemented filtering methods reduces the average processing time of a laser data set by a factor of 5 while the transitional error $\|\boldsymbol{t}\|$ can still be kept below 1% of the distance covered after 590 ICP-registrations. The resulting elevation maps are very promising according to a real-time capable implementation of an accurate mapping from 3D sensor data.

References

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