Real-time 3D Indoor Mapping Using the Normal Distributions Transform

Dylan Campbell and Mark Whitty
School of Mechanical and Manufacturing Engineering, University of New South Wales, Australia

This paper presents an efficient approach to 3D indoor mapping that balances speed, completeness and accuracy by continuously registering scans acquired from a rotating LiDAR sensor mounted on a moving platform. To construct a coherent 3D map without relying on GPS, external infrastructure or the long-term accuracy of onboard odometry, the continuously acquired range data is segmented into 3D pointclouds, which are aligned using a scan registration algorithm.

The main contribution of this work is the integration of the 3D Normal Distributions Transform (3D-NDT) scan registration algorithm with mobile LiDAR to create a system for real-time interior surveying. NDT's robustness to significant rotations between scans solves the primary problem associated with scanning while moving: that rotations are less controllable in dynamic scanning. Moreover, since the registration is independent of the odometry, slip can be detected and any slip-deformed scans can be removed from the map, further improving the accuracy of this approach.

Another advantage of this approach is the relative completeness of the generated map: a moving sensor is able to view features from many different viewpoints, reducing the likelihood of areas not being observed. As well as the speed gains inherent in mapping continuously rather than at discrete locations in a "stop-and-scan" fashion, the processing is performed in real-time. This provides the operator with immediate feedback on mapping quality, so complete coverage can be guaranteed.

Furthermore, all six degrees of freedom are considered for the vehicle's pose (x, y, z, roll, pitch and yaw), allowing inclines and unstructured natural environments to be navigated and mapped. In addition, this paper presents a parametric study of several physical considerations that arise from continuous mobile LiDAR scanning, including constraints on the vehicle's velocity and laser yaw rate.

The maps generated using this approach were considerably more accurate (as evaluated against the ground truth) than those generated using dead-reckoning alone. Also, the completeness of the map was found to be greater than that produced by static scanning, for a set of standard configurations. Finally, the efficiency of the approach was shown in its ability to generate a full 3D representation of a complex 3,000 square metre building in the time required to drive the platform through all the rooms.