Planar Surface Mapping

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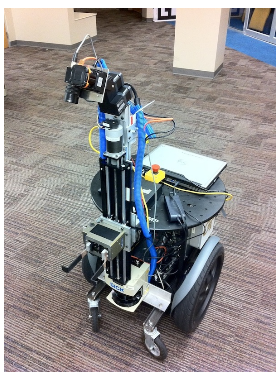
Introduction

We present a feature based mapping technique that allows for the use of planar surfaces such as walls, tables, counters, or other surfaces as landmarks. These planar surfaces are detected in 3D point clouds, and provide measurements via their surface normal and perpendicular distance. We also map the convex hulls of the observed planar patches and use these for data association, allowing multiple non-overlapping coplanar landmarks to exist in the map. Maps of such planar surfaces could be useful for semantic mapping, and could benefit mobile manipulation tasks.

Robot Platform & Sensor Data

The robot used in this work is equipped with a Hokuyo UTM-30-LX laser range finder mounted on a Directed Perception DP-46-70 pan tilt unit. Tilting the 2D laser scanner allows 3D point cloud data to be collected, by using the sensor location and tilt angle to project the points into 3D.



The robot platform used in this work is shown above. The 3D laser sensor can be seen at the top of the robot.

Plane Detection

3D point clouds collected throughout the area to be mapped are processed in order to detect planar surfaces. To do this, we use the well known RANdom SAmple Consensus (RANSAC) method for model fitting. In our case, we are fitting planes to the full point cloud to determine the largest plane present in each cloud. We then remove the inliers associated with this plane from the point cloud, and repeat the process in order to detect additional planes. Convex hulls are then calculated for detected planar regions.

For much of our point cloud processing, we use the Point Cloud Library (PCL) developed by Rusu and others at Willow Garage, which includes a variety of tools for working with 3D point cloud data including RANSAC plane fitting, outlier removal, and euclidean clustering methods.

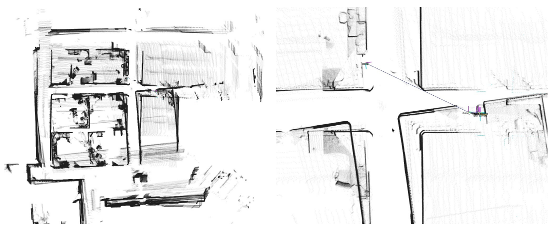
Plane Mapping

Our SLAM system uses the GTSAM library developed by Dellaert [1]. GTSAM approaches the graph SLAM problem by using a factor graph that relates landmarks to robot poses through factors. The factors are nonlinear measurements produced by measuring planar surfaces detected in point cloud data. While planar surfaces are mapped in 3D, note that we constrain our robot trajectory to the 2D groundplane, so poses consist of (x, y, θ).

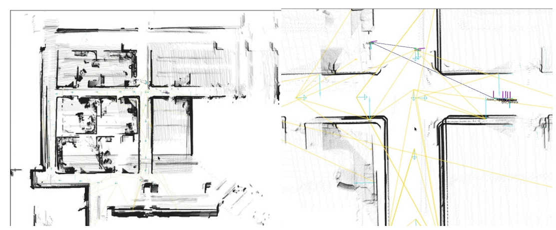
Using the planar surface measurement function and its associated Jacobians, we can utilize planar normals and perpendicular distances as landmarks in our SLAM system. During optimization, the landmark poses and robot trajectory are optimized. After optimization, the resulting map consists of planar surfaces as represented by their surface normals and convex hulls in the map frame, along with the optimized robot trajectory.

Mapping Results

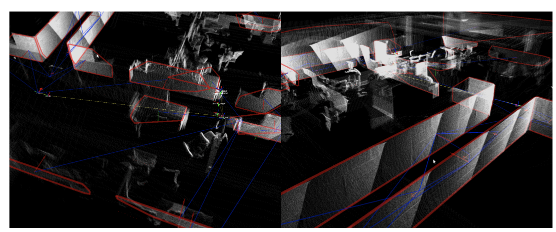
The mapping system was tested on data collected at the Georgia Institute of Technology's College of Computing building. Mapping results are presented in the figures below.



Shown here are pointclouds plotted in the odometric coordinate frame without optimization. An overview is shown on the left, with closeup on the right. Note the significant error in alignment.



Pointclouds plotted in the map frame, after optimization. An overview is shown on the left, with closeup on the right. Note that the alignment has been much improved.



The convex hulls of the mapped planar regions can be seen in the above figures, showing the location and extent of the mapped surfaces.

Conclusion

- Point cloud data can be processed to detect planar surfaces along with their convex hulls.
- Planar surfaces can be mapped using their surface normals and perpendicular distances, along with their convex hulls.
- The resulting maps include information on both the locations and extent of surfaces, which could be useful for semantic mapping and mobile manipulation tasks.
- Mapping results were presented for an office environment demonstrating the system's ability to loopclose.

References

[1] F. Dellaert, M. Kaess Square Root SAM: Simultaneous Localization and Mapping via Square Root Information Smoothing *IJRR*, Vol. 25 (12), 2006.