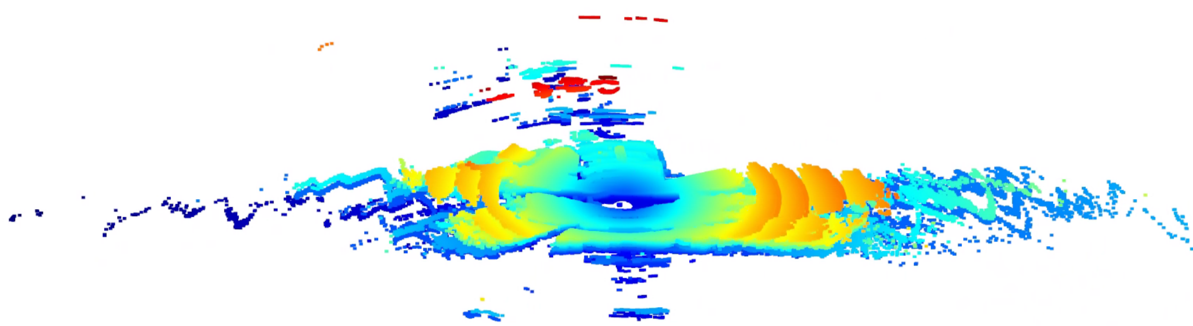
LiDAR-based Mapping

The input rosbag contains point clouds obtained from a Velodyne LiDAR, IMU measurements and the tf tree for the robot in the body frame. The objective is to obtain a point cloud map of the scene.

The first step is to read the point clouds from the rosbag, and there are 901 frames with point clouds expressed in the local frame. Next, the point clouds are downsampled for efficient processing. Initial point clouds are quite noisy since their alignments are not optimized, as can be seen below.

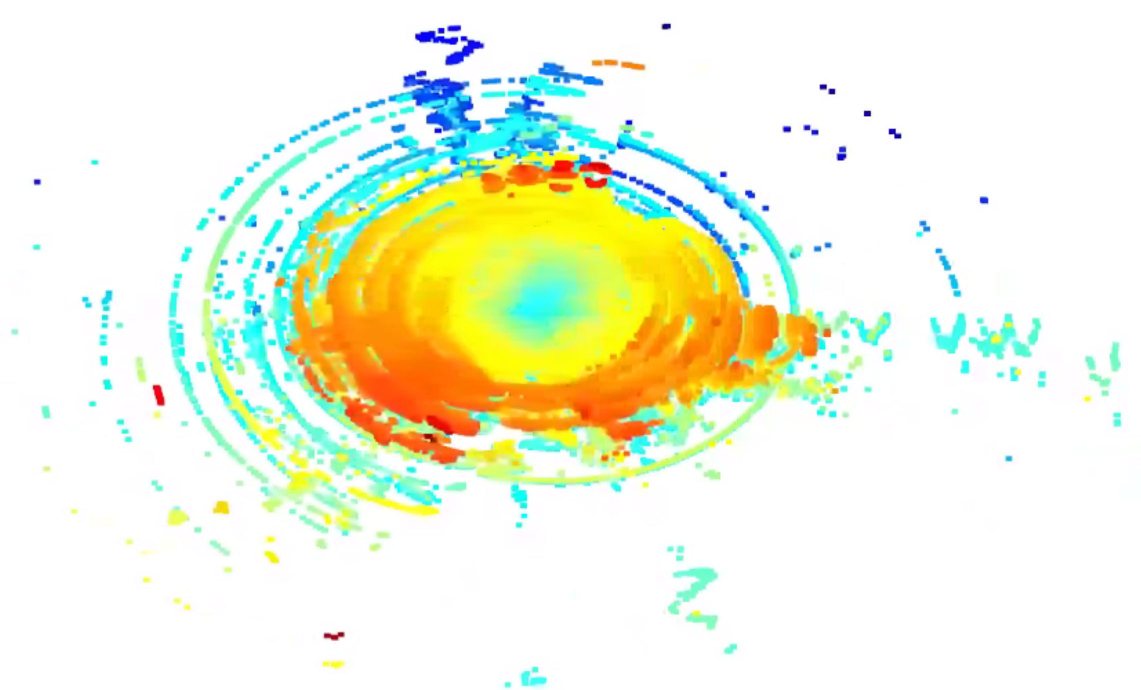


The second step is to do pose graph optimization. The node in the graph represents the point cloud Pi from each frame i associated with a transformation Ti in SE(3), which transforms the point cloud Pi from the body frame to the world frame.

The set of poses {Ti} are the variables to be optimized. Due to the limited observability, T0 is set to be the origin of the world frame. An edge in the graph connects two nodes that overlap, whereby each edge contains a transformation Ti,j aligning Pi to Pj. The relative transformations are estimated via Iterative closest point (ICP).

Since the local transformations are prone to drift, global loop-closures are also included in the edges. These edges connect non-neighboring nodes and the transformation is obtained via global registration [1].

After we define the nodes and obtain the edges, we can proceed to do the least squares minimization. This step employs the Levenberg–Marquardt algorithm to minimize the residual, i.e. the euclidean distance between the transformed point clouds and the original point clouds. The pose graph optimization is implemented with Open3D [2]. The optimized point cloud map is below, which has a better alignment compared with the initial map.



This project only uses the Velodyne LiDAR, and IMU measurements could be used for future works to estimate the gravity for better alignment. Inertial data can also help handle the case when there are few overlapping point clouds between the frames [3][4].

References

- [1] TEASER: Fast and Certifiable Point Cloud Registration
- [2] Open3D – A Modern Library for 3D Data Processing
- [3] LeGO-LOAM: Lightweight and Ground-Optimized Lidar Odometry and Mapping on Variable Terrain
- [4] Real-Time Loop Closure in 2D LIDAR SLAM