Clustering, Object Tracking for Underground Robotics

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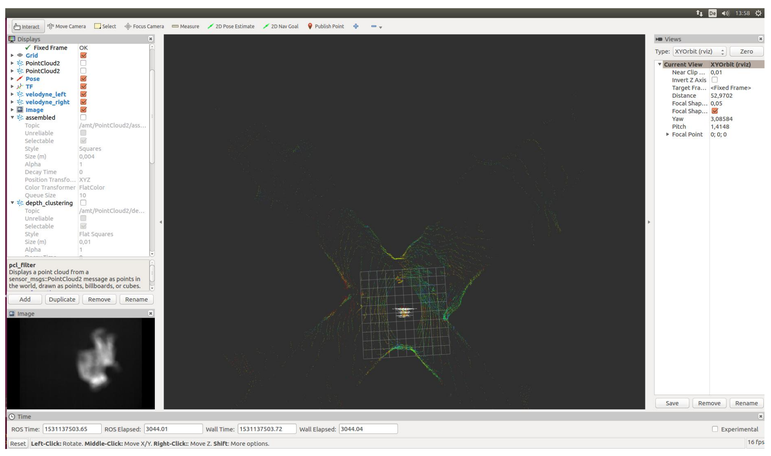
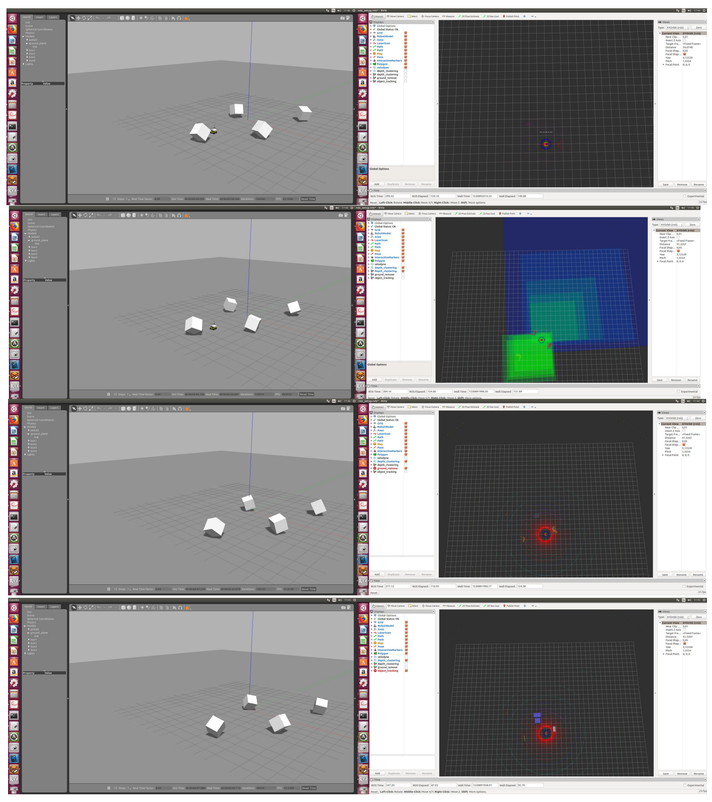
BACKGROUND

Mining technology experience a breakthrough in the exploration of tunnel detection with the development of robotics. Underground robotics can be one safer solution for tunnel detection. In the mining tunnel environment, Due to the complexity of the surface of walls and ground in the tunnel, underground robots have an extent of obstructions to recognize objects while it is wandering in the underground environment. Therefore, depth clustering and object tracking can be optimizing the results from the scanner or radar can improve the visualization of moving objects in tunnels

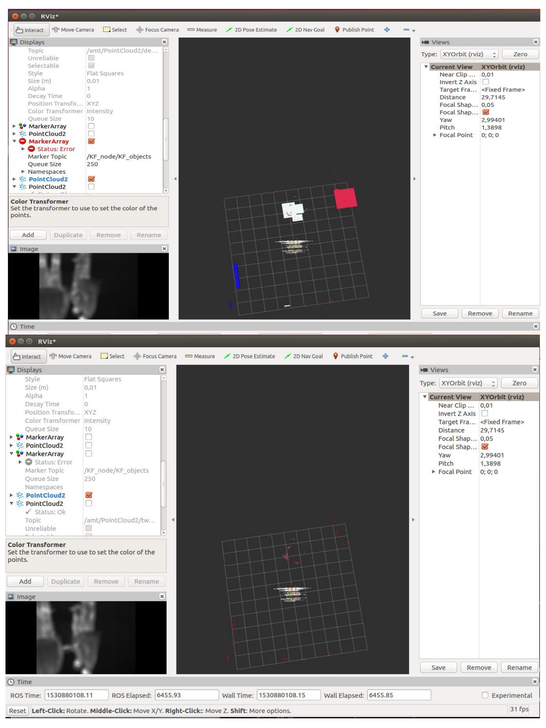
In this figure, the Point cloud map cannot recognize moving objects, walls, and ground in the tunnel environment.



Point clouds map in tunnels, which are collected by Velodyne 3D scanner



the procedure of obtaining tracking objects in simulation environment



the results of tracking objects & the results of Pointcloud2 filter (remove ground and walls)

RESULTS

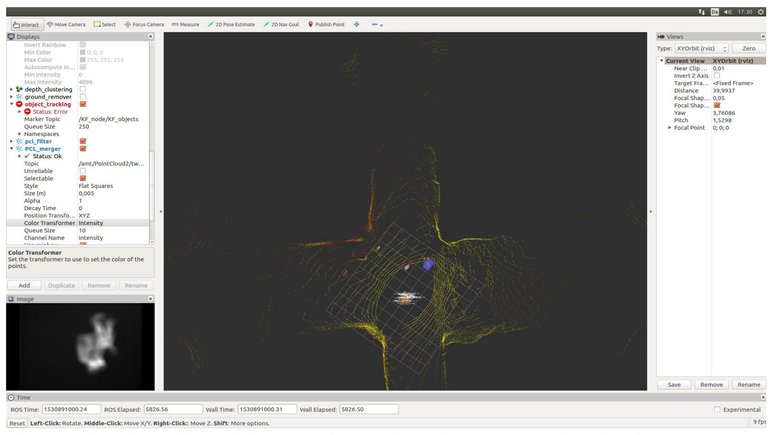
To an extent, the results get the accurate object tracking of moving objects in both simulation and tunnel environment.

Simulation Environment

The point clouds are created from Velodyne simulator and show the results to the Rviz topics. In the simulation environment, the third picture shows the effect of clustering nodes(marker array) after the ground removed. And the last images shows the object tracking (different colors.)

Velodyne Dataset

The point clouds assembler and point clouds merging methods require both collecting real-time point clouds and merging from the left and right Velodyne topics. In addition, Pointcloud2 filter is used to filtering out walls and ground. The final step is similar to the simulation test, clustering and object tracking to assembled point clouds.



the results of tracking objects and tunnel environment (point clouds)

CONCLUSIONS

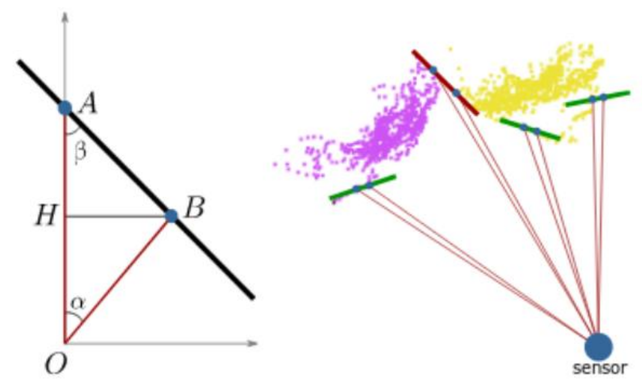
This project aims to get the precise clustering objects and tracking objects. Mostly, the moving objects were clustered correctly and tracked which rely on regular linear movement. To improve the accuracy of clustering and tracking, we create an algorithm for the non-linear shift should be considered (e.g., Extended Kalman Filter).

METHODS

Firstly, the methods implemented in a test environment, which can give apparent effects on the results. After that, the Velodyne scanners collect the dataset for the depth clustering and the object tracking.
After that, the dataset from the Velodyne scanners is collected for the depth clustering and the object tracking.

Depth Clustering

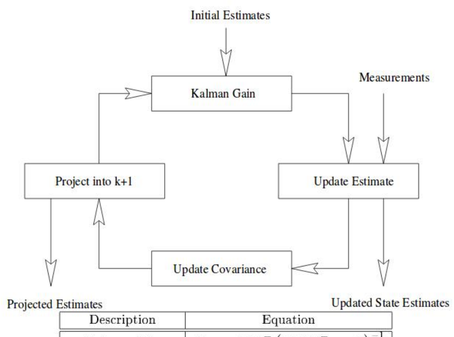
The Depth clustering for tunnels is a framework to distinguish different objects from point clouds. The theory of clustering is base on the angle β between the connected line of two points in the point clouds and the connected line from the sensor to one of two points which has a longer distance. These two points show two different objects if the β is bigger than the predefined threshold θ.



example scene with two pedestrians [1]

Object Tracking

The Kalman filter can be considered as a feedback system. This feedback system consists of predict and update systems. The initial states provide the position and the velocity of the object. The calculation of predicted states and predict covariance is initialized by initial states and initial covariance go through predict system. The update system updates the final states and covariance and gives the value to initial states and covariance again.



Description	Equation
Kalman Gain	$K_k = P'_k H^T \left(H P'_k H^T + R \right)^{-1}$
Update Estimate	$\hat{x}_k = \hat{x}'_k + K_k (z_k - H\hat{x}'_k)$
Update Covariance	$P_k = (I - K_k H) P'_k$
Project into $k+1$	$\hat{x}'_{k+1} = \Phi \hat{x}_k$ $P_{k+1} = \Phi P_k \Phi^T + Q$

Kalman Filter Recursive Algorithm [2]

References
[1] B. Igor, S. Cyrill, “Fast Range Image-Based Segmentation of Sparse 3D Laser Scans for Online Operation”, Universität Bonn
[2] L. Tony, “Tutorial: The Kalman Filter”, http://web.mit.edu