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Point Cloud Segmentation of Infrastructural Steel

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Analyzing steel structures from point cloud data gathered with an Unmanned Aerial Vehicles (UAVs) has great potential in various industries. The accurate understanding of the geometry of steel infrastructure is essential for the autonomous navigation of a UAV within and along these structures. Real-time analysis of 3D measurements obtained for instance from a pair of stereo cameras or from a time-of-flight camera enables the creation of models that accurately represent the complex geometry of steel structures.

The objective of this project was to develop an efficient point cloud segmentation method for real-time analysis of steel structures, which could be integrated into an autonomous UAV to assist its navigation.

The Hough Transform was chosen as the method for line detection. It employs a voting scheme to identify the line that passes through the greatest number of points in the collected point cloud. I used an open source library, presented in Christoph Dalitz et al.'s paper, "Iterative Hough Transform for Line Detection in 3D Point Clouds." They implemented a 3D Hough Transform, which they applied to the full point cloud and associate the most voted line with several points and iteratively removes them from the point cloud until no points are left. Although the provided implementation was able to produce adequate segmentations, it encountered several issues that affected its overall performance:

1. It exhibited high sensitivity to its parameter settings, such as the point to line distance threshold, maximum number of lines returned, and minimum number of votes required for a line.
2. It did not prioritize vertical or horizontal beams, treating them equally.

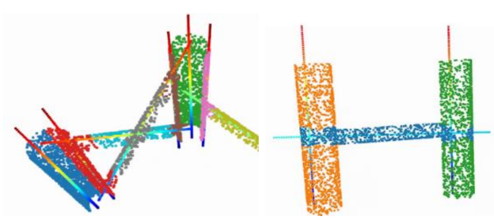

Fig. 1: Illustration of impact of the parameters on the segmentation. On the left, several lines are wrongfully fitted to the same element, while on the right, the segments are correctly identified.

This made it challenging to achieve optimal results as these parameters needed to be finely tuned.

To address these issues, modifications were made to improve the segmentation algorithm. The modified code assigned more weight to vertical lines, acknowledging their importance as a base in steel structures and a fusion step was introduced to merge lines that were close and parallel, making the algorithm mitigate the influence of parameters other than the distance threshold and resulting in decreased sensitivity on this parameter for line detection.

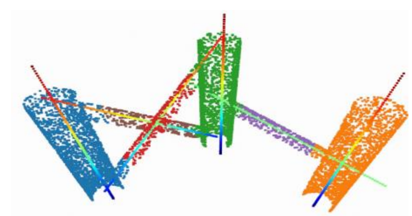

Fig. 2: Resulting impact of proposed improvements, yielding better segmentation results.

These improvements significantly enhanced the accuracy of the segmentation. The modified algorithm successfully identified beams and cylinders within the point cloud, even in complex scenarios with a limited number of points and a noisy point cloud.

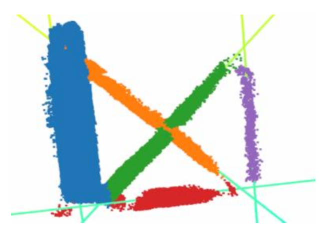

Fig. 3: Segmentation performed on real world data collected with a time-of-flight camera.

In conclusion, the developed segmentation method based on the Iterative Hough Transform exhibited great potential for real-time analysis of steel structures. Its ability to handle complex arrangements, accurately segment the point cloud, and maintain reasonable runtime complexity makes it a good candidate for structural analysis applications. Future work involves further fine-tuning and testing of the algorithm on a real UAV to ensure its effectiveness in various real-world scenarios.