SS 2023-2024, SMT, DISAL-SP188 Project Summary

Geometric Reconstruction of a Steel Structure from onboard Sensor Data

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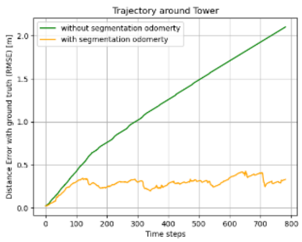
This project presents an investigation into the geometric reconstruction of steel structures based on data acquired from onboard sensors. The objective is to develop a method for creating accurate 3D models of steel infrastructures using sensor data, which is inherently noisy and complex. This approach is motivated by the need for more efficient and error-resistant methods for structural inspection, moving beyond traditional manual techniques that are often time-consuming and costly.

The methodology involves the collection of spatial data through Time of Flight (ToF) sensors mounted on drones. This data is then processed to filter out noise and extract meaningful geometric information about the structure. For this purpose, the algorithm is based on the 3D Hough transform. The project worked on Robot Operating System (ROS) and Webots for the simulation part.

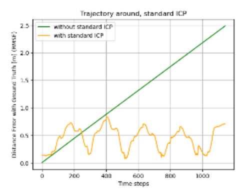
One significant challenge is resistance to noise. Accurate reconstruction of the structure requires precise knowledge of absolute position and orientation. Various odometry methods based on point clouds were tested to address this.

The first method used segmentation from the 3D Hough transform. The algorithm extracted segments from the point cloud and readjusted the drone's position based on these segments. While this simple algorithm showed good results, it could suffer from inaccuracy if the drone lost sight of the structure. The graphs show the position error in meters: green indicates the error without odometry correction, and orange shows the error after correction.

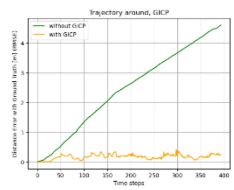


Segmentation odometry

The second part involved experimenting with odometry using the Iterative Closest Point (ICP) algorithm and its variants, such as 3 DoF ICP and Generalized ICP (GICP). These algorithms compute positional errors based on the captured point clouds.



ICP



GICP

The standard ICP often failed due to incorrect orientation corrections, which compounded over time, leading to significant errors. The 3 DoF ICP performed better but still suffered from incorrect convergence. While being 3 to 4 times more computationally expensive, the GICP, provided excellent noise reduction and resolved the structure deformation issues seen with standard ICP (fig.1 GICP reconstruction). It also demonstrated robustness against yaw noises and yaw drift.

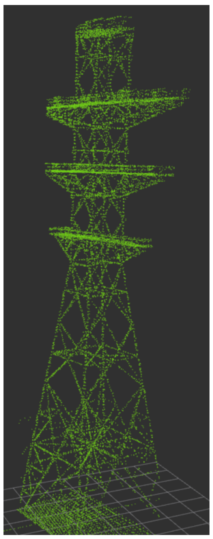


Figure 1

In summary, our findings demonstrate the potential of the 3D Iterative Hough Transform and GICP for real-time segmentation and geometric reconstruction of steel structures. Despite the challenges related to noise and computational demands, these methods significantly enhance the accuracy and reliability of structural inspections using drones. Future work could focus on path planning to prevent the drone from losing sight of the structure, thereby improving odometry and overall segmentation.