Building dense reconstructions with SLAM and Spot

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Errors in the construction field are costly both in terms of money and time. In 2018, the Swedish authority Boverket published a report surveying faults and damages related to construction errors. They estimated that the annual cost related to construction errors exceeded 80 billion SEK [1]. Having access to dense reconstructions, meaning accurate 3D representations, of ongoing construction projects could provide means for error detection and documentation of the actual outcome. SLAM is an acronym for *Simultaneous Localization and Mapping* and it is the process of creating a map of the environment that the robot visits while simultaneously trying to estimate its pose in relation to the environment. In scenarios where measurement data cannot be georegistered due to the absence of GPS coverage or other means of positioning sensors in the environment, SLAM could instead be used to build a map of the environment.

In this thesis project, *Spot*, the quadruped mobile robot designed by Boston Dynamics, was evaluated as a platform for site inspection at construction sites. By utilizing the sensor configuration and Spot's ability to autonomously navigate dynamic and unstructured environments, dense reconstructions could be created. This was done by integrating Spot's sensors, both depth cameras and LiDAR, and odometry into the *Robot Operating System* framework. The SLAM library RTABMap [2] was then utilized to build dense reconstructions from the sensor data and odometry.

The project focused on the evaluation of both the localization performance of the SLAM algorithm chosen and the accuracy of the reconstructions when utilizing the data from the robot platform. The localization performance was evaluated by computing the absolute trajectory error for an outdoor experiment with ground truth data collected from a high resolution GPS. The results from the localization experiments showed that an RMS error in the decimeter range could be acheived for paths spanning further than 100 meters.

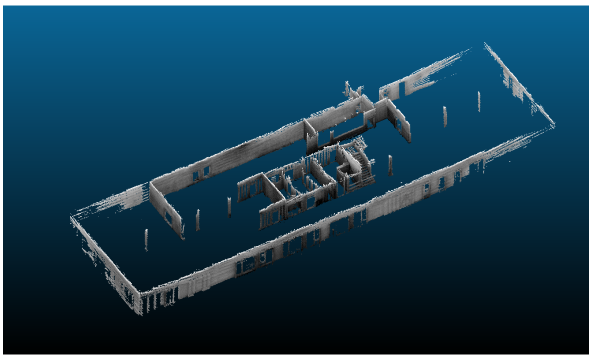

Figure 1. Segmented LiDAR reconstruction.

The accuracy of the reconstruction was evaluated by comparing it against both a building information model and a method based on geometric fitting for parts of the reconstruction. Weekly experiments were conducted where the robot navigated autonomously at a construction site, during which the data from the sensors on Spot and the robot's estimated egomotion was recorded. The data collected could then be used to perform the mapping in an offline setting. The results from the experiments showed that the accuracy of the reconstructions acheived centimeter precision. The results indicated that the range accuracy of the LiDAR system used was the limiting factor.

All though the results were promising, it was concluded that the accuracy of the reconstructions were inadequate. The current solution was found to not be fully sufficient to be used for site inspection. However, the reconstructions could still be useful for tracking the progress of ongoing constructions.

References

[1] Boverket. *Kartläggning av fel, brister och skador inom byggsektorn.* 2018. URL: https://www.boverket.se/sv/om-boverket/publicerat-av-boverket/publikationer/2018/kartlaggning-av-fel-brister-och-skador-inom-byggsektorn/ (visited on 2022-01-24).

[2] M. Labbé and F. Michaud. "RTAB-Map as an open-source lidar and visual simultaneous localization and mapping library for large-scale and long-term online operation". *Journal of Field Robotics* **36**:2 (2019), pp. 416–446. DOI: https://doi.org/10.1002/rob.21831. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/rob.21831. URL: https://onlinelibrary.wiley.com/doi/abs/10.1002/rob.21831.

[3] O. Nilsson. *Building dense reconstructions with SLAM and Spot.* MSc Thesis TFRT-6158, Department of Automatic Control, Faculty of Engineering, Lund University. 2022. URL: https://lup.lub.lu.se/student-papers.