Pointclouds Integration from Aerial and Ground View Exploiting Normal Vector and Pose Graph Optimization

Minwoo Jung[1] and Ayoung Kim[1*]

***Abstract*— Recent advances in simultaneous localization and mapping (SLAM) have enabled the construction of accurate maps through various systems. In particular, unmanned aerial vehicles (UAV) and unmanned ground vehicles (UGV) are two of the systems being utilized. Using two platforms necessitates the combining of each map to alleviate disadvantages and exploit advantages. In this paper, we propose a method for integrating UAV and UGV maps exploiting normal vector and Pose Graph Optimization (PGO). Our method creates a scan context using a normal vector, finding an overlapping area between the two maps. Furthermore, the trajectory of UGV is placed on the UAV map by utilizing the anchor node and PGO. Then, the partial map from UGV is combined with the UAV map to integrate them. We validate our method at a large construction site.**

I. Introduction

Over the last few decades, researchers have advanced SLAM to be suitable for any system, including UAV and UGV. UAV is proper for mapping a wide area but has a disadvantage in that detailed characteristics cannot be obtained. On the contrary, UGV can map detailed features on the side and near the ground. However, it is time-consuming and only places where UGV can pass are mapped.

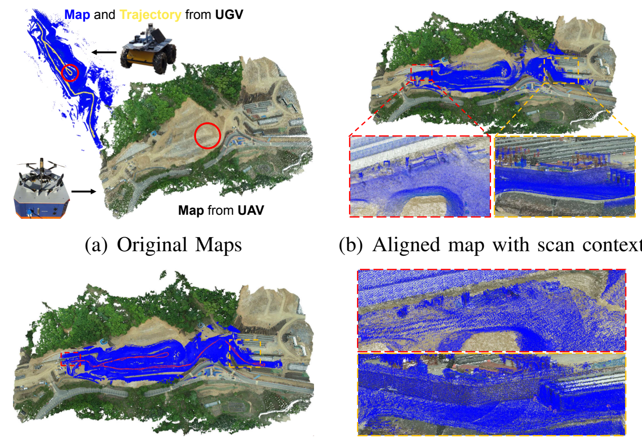
The best way to mitigate the shortcomings is to integrate them, finding overlapping areas on the maps. But for this, researchers need to figure out how to find them. Kim et al. [1] proposed a scan context exploiting the greatest height, not being effective since the observable height of the two systems is different. Even if overlapping areas are found and matched, the further away from the matching point, the less the matching accuracy because the maps are not identical.

To overcome these problems, we propose a scan context exploiting normal vector and PGO with anchor nodes as in [2]. We aim to utilize the trajectory of UGV to place it on the UAV map and combine the partial maps of each trajectory.

II. Two step integration of UAV and UGV map

In order to extract the normal vector from each map shown in Fig. 1(a), principal component analysis (PCA) was utilized to align the axes. Then, bins were formed from the periphery of each UGV trajectory, and the normal vector was obtained by approximating the plane within the bin, using random sample consensus (RANSAC) to remove outliers. The KD-tree was formed based on scan contexts generated using the normal vector in the z-axis at each trajectory. In the same way, we created a scan context from the downsampled UAV map to retrieve similar areas in the KD-tree. If the distance of the matching pair was below the threshold, the transformation was computed through Iterated Closest Point (ICP). Fig. 1(b) shows the aligned map not fitting at ends.

To align the maps, the trajectory of UGV was placed on the UAV map. Two identical graphs whose nodes and edges indicate the location of the trajectory of UGV and the transformation between the nodes were created. We set the matched location as the anchor node and extracted partial maps of UAV and UGV from the same index node near the anchor node in each graph. The relative transformation connecting the same index nodes between graphs was obtained by ICP, and the graphs were optimized while the UGV graph was being fixed. By applying the same method from around the processed node to the end, all nodes in the UAV graph were updated. Finally, the trajectory of UGV was placed on the UAV map as in Fig. 1(c). The maps are integrated by merging the partial map around each node of the UGV graph to the location of the same index node on the UAV graph.



(a) Original Maps (b) Aligned map with scan context

(c) Top view of integration map (d) Close-up of integration map

Fig. 1. Overall pipeline. (a) This shows the initial UAV map (RGB) and the UGV map (blue), not aligning at all. Red circles indicate the overlapping area. (b) Maps are aligned after finding the matching pair. They are not matching at the ends of the map. (c) shows the integrated map after the PGO is done. The red dot is the trajectory of UGV on the UAV map. (d) shows that the parts that did not fit in (b) are matched.

[†]This work was supported by a grant from NRF (2020R1C1C1006620).

[1]M. Jung and A. Kim are with the Department of Mechanical Engineering, SNU, Seoul, S. Korea [moonshot, ayoungk]@snu.ac.kr

References

[1] G. Kim, S. Choi, and A. Kim, “Scan context++: Structural place recognition robust to rotation and lateral variations in urban environments,” *IEEE Trans. Robot.*, vol. 38, no. 3, pp. 1856–1874, 2022.

[2] B. Kim, M. Kaess, L. Fletcher, J. Leonard, A. Bachrach, N. Roy, and S. Teller, “Multiple relative pose graphs for robust cooperative mapping,” in *Proc. IEEE Intl. Conf. on Control, Automat. and Robot.*, 2010.