AGILE: GIScience Series, 3, 52, 2022. https://doi.org/10.5194/agile-giss-3-52-2022
Proceedings of the 25th AGILE Conference on Geographic Information Science, 2022.
Editors: E. Parseliunas, A. Mansourian, P. Partsinevelos, and J. Suziedelyte-Visockiene.
This contribution underwent peer review based on a full paper submission.

Precision mapping through an RGB-Depth camera and deep learning

Georgios Petrakis[1], Panagiotis Partsinevelos[1]

[1] School of Mineral Resources Engineering, Technical University of Crete, Chania, Greece

Correspondence: gkpetrak@gmail.com

Abstract. Recent progress on geospatial and sensory, artificial intelligence technologies defines the necessity to revisit conventional geodetic techniques for surveying and mapping. In the present study, an alternative novel surveying method is implemented, which enables the precise localization of characteristic points in any area, including unknown and GNSS-denied environments, by simply using low-cost cameras. The methodology is based on novel algorithms that combine simultaneous localization and mapping (SLAM), deep learning, point-cloud processing, along with coordinate systems' transformations. The camera system subsequently detects and localizes target markers and reconstructs a 3D environment with relative coordinate estimations under a few centimeters-level of accuracy.

Keywords. SLAM, deep learning, surveying, precision-mapping

1 Introduction

Nowadays, the evolution of satellite technology, uncrewed aerial vehicles (UAV), passive or active sensors and data science, results in substantial advances in geodetic instruments and techniques.

Traditional surveying methods may provide high level of accuracy, yet, they still remain time consuming and require significant human effort and pricey equipment in the field [1]. On the other hand, GNSS (Global Navigation Satellite Systems) surveying methods, have to confront challenges of precise localization due to insufficiency of satellite coverage and GNSS signal in urban environments or areas with dense vegetation [2]. Concerning photogrammetry, classical techniques need an accurate establishment of control points and high computational requirements during and after the field work and data processing respectively. Instead, modern techniques such as "direct georeferencing" require additional equipment like a GNSS receiver and an IMU (inertial measurement unit) which increase the equipment cost [3]. Laser scanning techniques have become increasingly popular in recent years combining accurate and speed mapping, however they involve quite expensive equipment.

The present study, proposes a cost-effective, rapid and efficient surveying solution for GNSS-denied environments where a few minutes of walking with an RGB-D (Visual + Depth) camera on hand, are enough to map an area of interest. The proposed methodology which is based on SLAM with deep learning using the multi-line convergence (MLC) and plane alignment (PA) methods proposed in the previous stage of our work [4], is able to produce accurate coordinate estimations.

2 Methodology

The overall architecture of the methodology is presented in figure 1:

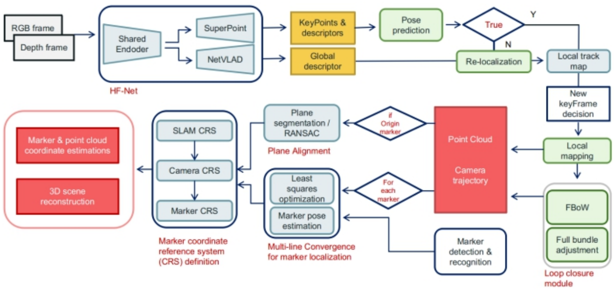

Figure 1 Overall architecture of the system

Initially, a visual marker which is defined as the origin of the local coordinate system is placed in the area of interest, while a number of visual markers which are defined as targets represent natural or artificial features.

During mapping, the RGB-D image frames are inserted to the HF-Net [5] neural network in order to extract keypoints and descriptors of the scene (feature extraction module), while the system based on keypoints and descriptors, predicts the camera pose, re-localizes the camera in case of a prediction failure and extracts new keyframes aiming to map the surroundings simultaneously (fig 2). Subsequently, multi-line convergence method localizes the markers in the scene using least squares optimization [4] while plane alignment defines the horizontal plane defining the pose of the origin marker [4]. Finally, all estimations are transferred from the initial SLAM based coordinate system, to the marker coordinate system which results in targets and point cloud coordinate estimations.

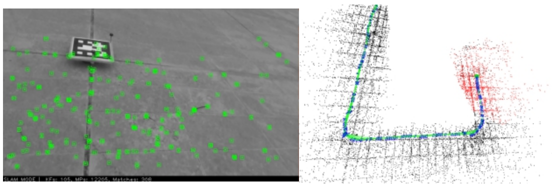

Figure 2 Feature detection and mapping. Left: Target marker based on ArUco library [6, 7]. Right: Point cloud, camera trajectory (green line) and keyframes (blue squares) extracted in real time

3 Results

To validate the present methodology four markers were used: one for the origin and three for the targets in a distance of about 5 meters while the camera followed a squared path.

Before the performance of the experiment, the markers and a number of characteristic points were measured using the total station for validation purposes. The origin marker is defined with the coordinates (0, 0, 0) in X, Y and Z axes, while the target markers were measured based on the origin marker.

The results of the experiment are presented in table 1. The errors are expressed as the absolute difference between ground truth and estimation in each axis.

Table 1. Coordinate estimations in X, Y, Z and related errors.

Target 1 (cm)	X	Y	Z
Ground truth	0	486.0	0
Estim	7.0	490.0	1.0
Error	7.0	4.0	1.0
Target 2 (cm)	X	Y	Z
Ground truth	-492.0	486.0	0
Estim	-491.0	493.0	-0.3
Error	1.0	7.0	0.3
Target 3 (cm)	X	Y	Z
Ground truth	-497.0	0	0
Estim	-486.0	-1.4	-8.0
Error	11.0	1.4	8.0

As presented in table 1, the errors in X varies from 1 cm (in target 2) to 11 cm (in target 3), the errors in Y have a range of 1.5 cm (in target 3) to 7 cm (in target 2) while the errors in Z varies from 0.3 cm (in target 2) to 8 cm (in target 3).

4 Conclusions

This study, proposed an alternative cost-effective surveying solution and mapping technique for unknown environments using only an RGB-Depth camera and at least one visual point. SLAM and deep learning, combined with multi-view geometry and point-cloud processing reinforce the scene understanding and reconstruct the 3D environment within a few centimeters of accuracy.

References

1. Carrera-Hernández J. J.; Levresse & P. Lacan G. (2020) Is UAV-SfM surveying ready to replace traditional surveying techniques?, International Journal of Remote Sensing, 41:12, 4820-4837, DOI: 10.1080/01431161.2020.1727049
2. Chiang K.W.; Tsai G.J.; Chang H.W.; Joly C.; EI-Sheimy N.; Seamless navigation and mapping using an INS/GNSS/grid-based SLAM semi-tightly coupled integration scheme, Information Fusion, Volume 50, 2019, Pages 181-196, ISSN 1566-2535, DOI: 10.1016/j.inffus.2019.01.004
3. Gabrlik, P. The Use of Direct Georeferencing in Aerial Photogrammetry with Micro UAV. IFAC-PapersOnLine 2015, 48, 380–385, DOI: 10.1016/j.ifacol.2015.07.064
4. Trigkakis, D.; Petrakis, G.; Tripolitsiotis, A.; Partsinevelos, P. Automated Geolocation in Urban Environments Using a Simple Camera-Equipped Unmanned Aerial Vehicle: A Rapid Mapping Surveying Alternative? ISPRS Int. J. Geo-Inf. 2020, 9, 425. DOI: 10.3390/ijgi907042
5. Paul-Edouard Sarlin, Cesar Cadena, Roland Siegwart, Marcin Dymczyk, From Coarse to Fine:

Robust Hierarchical Localization at Large Scale, Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 2019

6. R. Munoz-Salinas and R. Medina-Carnicer, “UcoSLAM: Simultaneous localization and mapping by fusion of keypoints and squared planar markers,” Pattern Recognition, p. 107193, 2020, DOI: 10.1016/j.patcog.2019.107193

7. Francisco J.Romero-Ramirez, Rafael Muñoz-Salinas, Rafael Medina-Carnicer, Speeded up detection of squared fiducial markers, Image and Vision Computing, vol 76, pages 38-47, year 2018, DOI: 10.1016/j.imavis.2018.05.004