Simultaneous Localization and Mapping for Field Robots(SLAM)

The second project inspection

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1. Background

The objective of simaltaneous localization and mapping is to bestow the capability of map-building and state estimation on robots, which is one of the most fundamental prerequisites for an intelligent robot. For field robots, one primary goal is to adjust and optimize SLAM algorithms and make robots operate smoothly on complex field terrains.

During the last two decades, great success has been achieved using SLAM for real-time state estimation and mapping with perceptual sensors such as a lidar or camera. The sensors detect surrounding environments and input the raw data into the processor, which estates the current state and constructs a map using SLAM algorithm.

SLAM is applied in a wide range of fields, including military, householding and automatic driving. Robot vaccums that adopt SLAM to enhance the route planning ability are perfect evidence to demonstrate the popularity of SLAM.

Mapping of a robot vaccum

2. Challenges

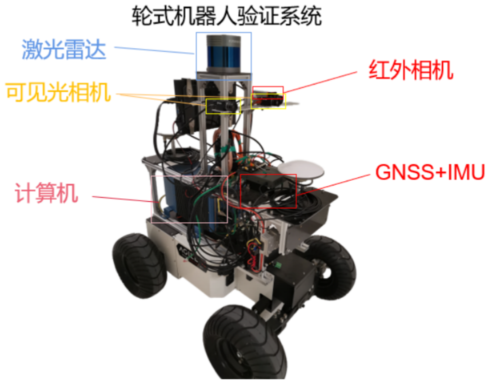
Various SLAM algorithms have been developed these days, while one vital flaw still remains. SLAM can achieve great performance on urban roads but perform poorly on field terrains with uneven ground surface and irregular obstacles like leaves and branches. THe detection and mapping accuracy is therefore negatively affected.

3. Objective

Our main objective to the end of this semester is to implement lidar-based Lego-Loam and optimized multi-sensor fusion algorithm LVI-SAM in our wheeled robot hardware platform and test its robustness in field environments on campus, and compare the two algorithms' performance. To realize the objective, we will localize the two algorithms and verify their feasibility with our self-recorded dataset.

4. Experiment Platform

- Hardware platform: Self-developed Wheeled Robot, personal computer
- Software platform: Ubuntu, ROS
- Data set: Self-collected mapping data on campus as well as official dataset on github



Self-developed Wheeled Robot

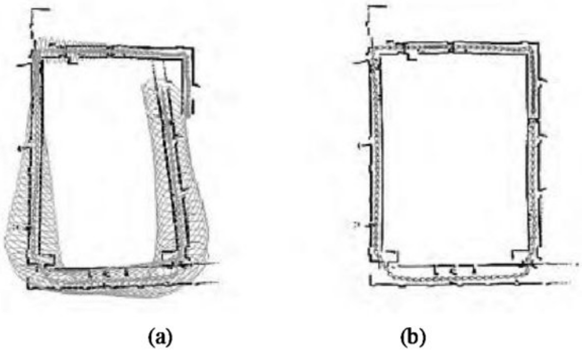
5. Related Work

During the last two decades, great success has been achieved using SLAM for real-time state estimation and mapping in challenging settings with a single perceptual sensor, such as a lidar or camera.

Lidar-based methods can capture the fine details of the environment at a long range, but such methods typically fail when operating in structure-less environments, especially in the wild fields.

Vision-based methods are especially suitable for place recognition and perform well in texture-rich environments, but their performance is sensitive to illumination and rapid motion, and sometimes fail to recognize surfaces with little texture details.

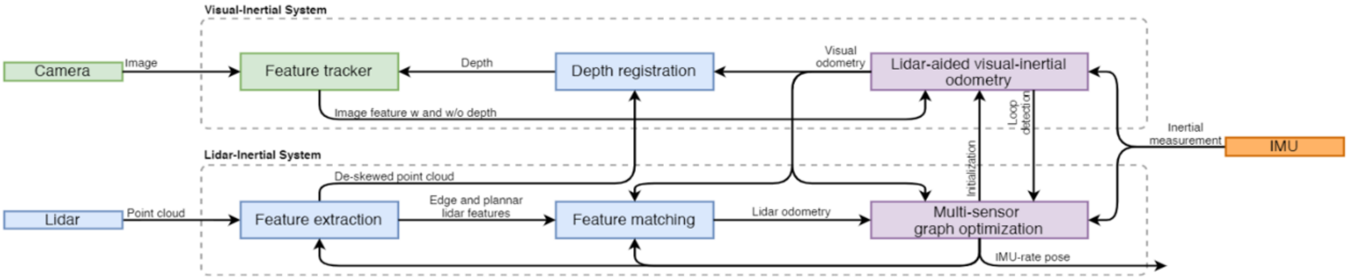
It is evident that the fusion of both modalities would complement the weakness of each other, but in order to perform such fusion algorithm with optimal performance, precise calibration must be guaranteed between sensors. Also, since the approach still relies on lidar, its performance would still be negatively affected by the structure-less environment and therefore accumulate errors that lead to the failure of loop detection because the algorithm fails to recognize an already visited scene due to deviation or sparse point clouds. The picture below shows the clear difference between a failed and a sucessful example.



Loop Detection

6. Innovation

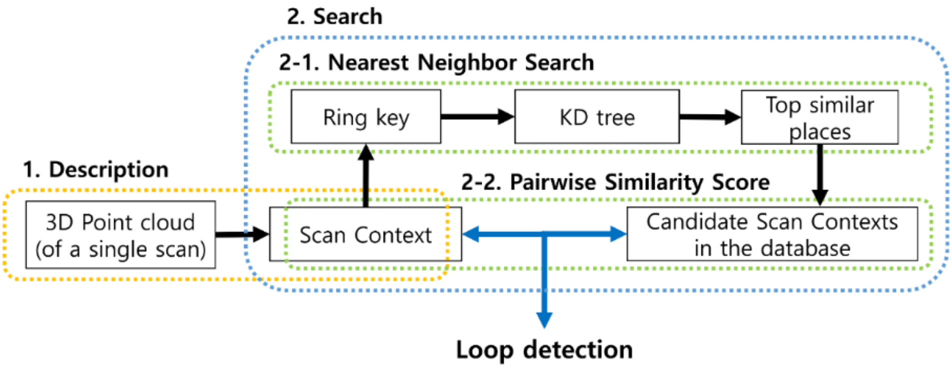
In outdoor environmet, the point cloud generated by lidar are often too sparse to demonstrate the characteristic of objects, therefore by introducing other sensors like cameras and IMU and integrating inputs from multiple modalities, we will be able to build maps with clear details. To achieve optimal performance in field terrains, we adopted LVI-SAM, a SLAM approach with the fusion of lidar, camera and IMU.



LVI-SAM

However, the weaknesses of such multi-modality approach remain. In outdoor environment, due to the sparseness of point clouds or potential deviation, the attempt to detect loops may fail because the processor may not be able to recognize a scene already visited. To conquer the problem of possible loop test failure, we have come up with the idea of applying Scan Context to LVI-SAM algorithm.

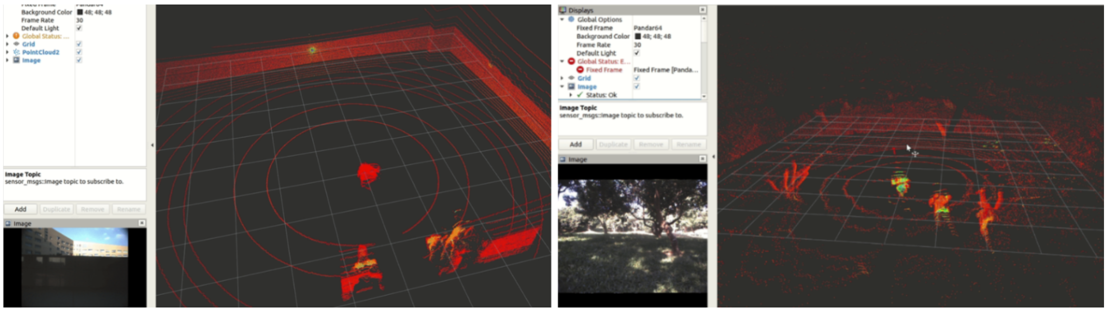
Scan Context is a global descriptor for lidar point cloud, which is especially designed for a sparse and noisy point cloud acquired in outdoor environment. It generates a unique circular 2.5D map for each scene based on the point cloud information, therefore creating a unique label for every frame when generating a map so that the algorithm can estimate the similarity between frames and calibrate the loop detection procedure.



Scan Context

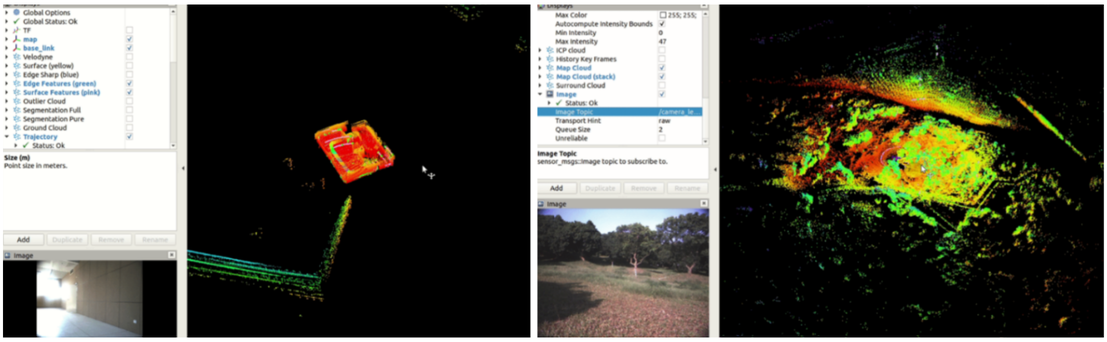
7. Initial Results

We have operated the wheeled robot on campus to verify the hardware capability and familiarize with the control procedure of the wheeled robot. In addition, we have recorded bag files that store the sensors' raw input data shown below. The left one was recorded in the engineering buiding and the right one was on one of the hillsides in SUSTech, representing the structured environment and the structure-less environment.



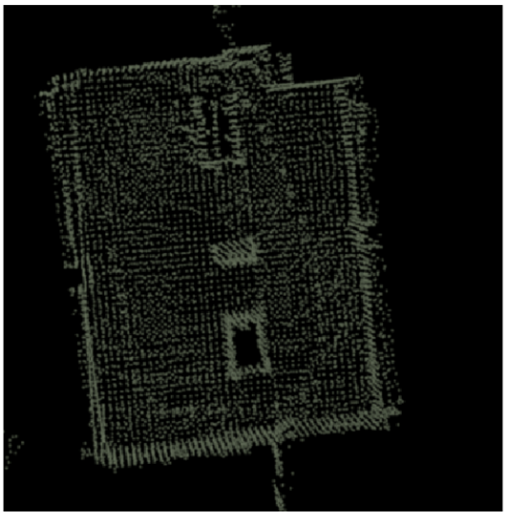
Two recordings of raw data input

Then we applied Lego-Loam algorithm to the self-recorded dataset. Lego-Loam is a lidar-based method, which means it relies solely on lidar and its point clouds to generate a map. The corresponding results are shown below.



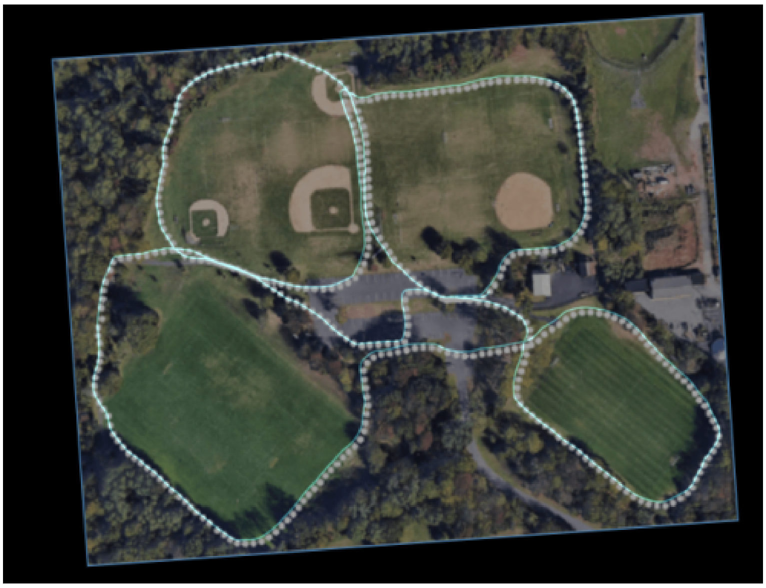
Maps generated by Lego-Loam

We observed ghosting in the final point cloud map, which indicates the fact that loop detection of Lego-Loam failed under the experiment circumstance.



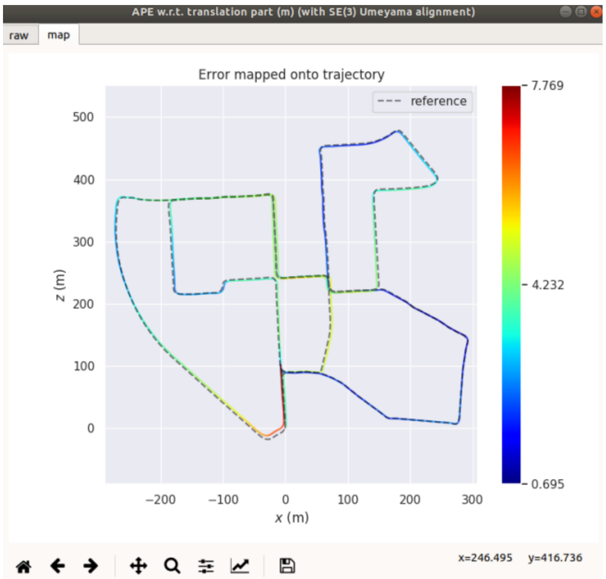
Ghosting

To verify the loop detection ability as well as the mapping accuracy of LVI-SAM, we ran LVI-SAM on a corresponding dataset which is compatible to the testing configurations. The final trajectory graph is shown below. The white dots represents the true trajectory of the robot, while the blue line represents the trajectory generated by the algorithm. It is obvious that these two trajectories match perfectly, denoting the success of mapping.



trajectory of LVI-SAM

This verification of trajectories is a bit rough. To precisely quantify the accuracy based on calculated numbers, we are currently working on adjusting a tool called EVO(evaluation of odometry and SLAM). We have ran testing examples that fits the requirements of EVO input. Graphs are shown below, denoting the trajectories as well as errors.



Heat map of errors

More experiments are to be conducted in the following months, covering the field tests of LVI-SAM and comparative tests of LVI-SAM and Lego-Loam to evaluate the feasibility of our optimization. Furthermore, precision evaluation is needed.

9. Scheduling

- 2022.3-2022.4: Study scan context technique. Learn to use EVO evaluation platform.
- 2022.4-2022.5: Apply scan context to LVI-sam algorithm to optimize its loop detection capability. Run test cases online to evaluate its performance.

- 2022.5-2022.6: Commence field tests and evaluate mapping precision.

10. Member Contribution

- Li Jiajun: manage project progress, assist with model modification, write the experiment report
- Kong Lingkai: operate the software platform and adjust codes, present our project
- Gu Juanyi: in charge of field tests, assist with model modification

Reference

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[2] Kim, G., Choi, S., & Kim, A. (2021). Scan Context++: Structural Place Recognition Robust to Rotation and Lateral Variations in Urban Environments. IEEE Transactions on Robotics.

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