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MC2MAP Algorithm
HILTI SLAM Challenge 2021

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Overview of the MC2MAP Algorithm

Our contribution is based on our company's core libraries which usually operate on a very different hardware setup. For this challenge, it was repurposed to (solely) make use of the Ouster OS0-64 lidar and ADIS16445 IMU data. It could potentially be operated with data from one of the other IMUs in the dataset, including the built-in Ouster IMU, however, no attempts have been made in this direction due to time constraints. No other sensors of the rig have been used.

Our MC2MAP algorithm consists of two parts: First, we estimate an initial solution to the problem and then perform a batch refinement.

The initial solution is estimated via laser-based SLAM using our algorithm MC2SLAM [1], which can also be used to perform real-time SLAM on the data. It solves a graph-based SLAM problem by tightly integrating IMU measurements with scan registration data. While this algorithm already performs very well on its own, it does not perform explicit loop closures and only compensates for the motion of the sensor during its revolutions at a local scale.

The refinement part of our algorithm strongly focuses on accuracy and the quality of the resulting maps over computation time. Therefore, in order to increase precision and accuracy, we perform explicit loop closing and subsequent batch post processing of the output of the MC2SLAM algorithm using an in-house algorithm that we call MC2MAP. In a nutshell, this algorithm uses a differentiable trajectory representation and simultaneously optimizes the full trajectory of the system, a compact representation of the map and IMU biases. The optimization makes use of all available ADIS IMU measurements, the explicit loop closing constraints, as well as a subsampled version of the laser data.

Laser data remains unfiltered, except for a range-based cutoff-filter for removing the measurements of the system's human carrier from the data.

No other calibration steps (extrinsics, IMU noise parameters, …) have been performed.

Processing of the datasets

All datasets except for the *Parking_1* dataset have been (pre-)processed with the MC2SLAM algorithm using the exact same settings. In the *Parking_1* dataset, there are almost no laser points except for ground points and points on moving people in the middle of the parking deck. Since we currently do not filter dynamic objects from the data, this specific situation poses a challenge for the default settings of our MC2SLAM algorithm. We therefore increased the cutoff-filter radius for this dataset, in order to let the algorithm focus on the few points in distant areas. The settings for post processing with the MC2MAP algorithm were the same for all datasets.
Some of the datasets had short time spans in which no IMU data was received. In these cases, an artificial constant velocity assumption was added to our optimization process.

Processing times

Results were obtained on a mid-class desktop AMD Ryzen 7 3700X processor with 32 GB of RAM. A GPU is not used for processing. We specify the processing time for MC2SLAM (first summand), post processing (second summand) as well as for the whole MC2MAP algorithm (sum).

Dataset	**Processing time [s]**	**Dataset**	**Processing time [s]**
LAB_Survey_2	126 + 608 = 734	Campus_1	465 + 1700 = 2165
Construction_Site_1	173 + 759 = 932	Campus_2	388 + 1185 = 1573
Construction_Site_2	380 + 1414 = 1794	IC_Office_1	196 + 951 = 1147
Basement_1	103 + 559 = 662	Office_Mitte_1	270 + 1445 = 1715
Basement_3	291 + 2244 = 2535	uzh_tracking_area_run2	89 + 657 = 746
Basement_4	311 + 2567 = 2878	Parking_1	673 + 2429 = 3102

About Vision & Robotics

V&R Vision & Robotics GmbH is a spinoff of the University of Koblenz-Landau in Germany. Based in the city of Koblenz, we build intelligent mobile systems as well as 2D/3D measurement systems together with our clients, including technology for accurate and precise multi-sensor surveying. V&R focuses on the sensor systems and the software for the sensor data analysis, registration and interpretation.

The algorithms used within this challenge are part of ongoing, partially unpublished projects. We are looking forward to getting in touch with people interested in this technology and its applications.

References

[1] **MC2SLAM: Real-Time Inertial Lidar Odometry using Two-Scan Motion Compensation**,
Neuhaus F., Koss T., Kohnen R., and Paulus D.
In *Pattern Recognition*, Brox, Thomas and Bruhn, Andrés and Fritz, Mario (editors), *Springer International Publishing*, Cham, 11269, pages 60-72, 2019.