Online global loop closure detection for RTAB-map SLAM

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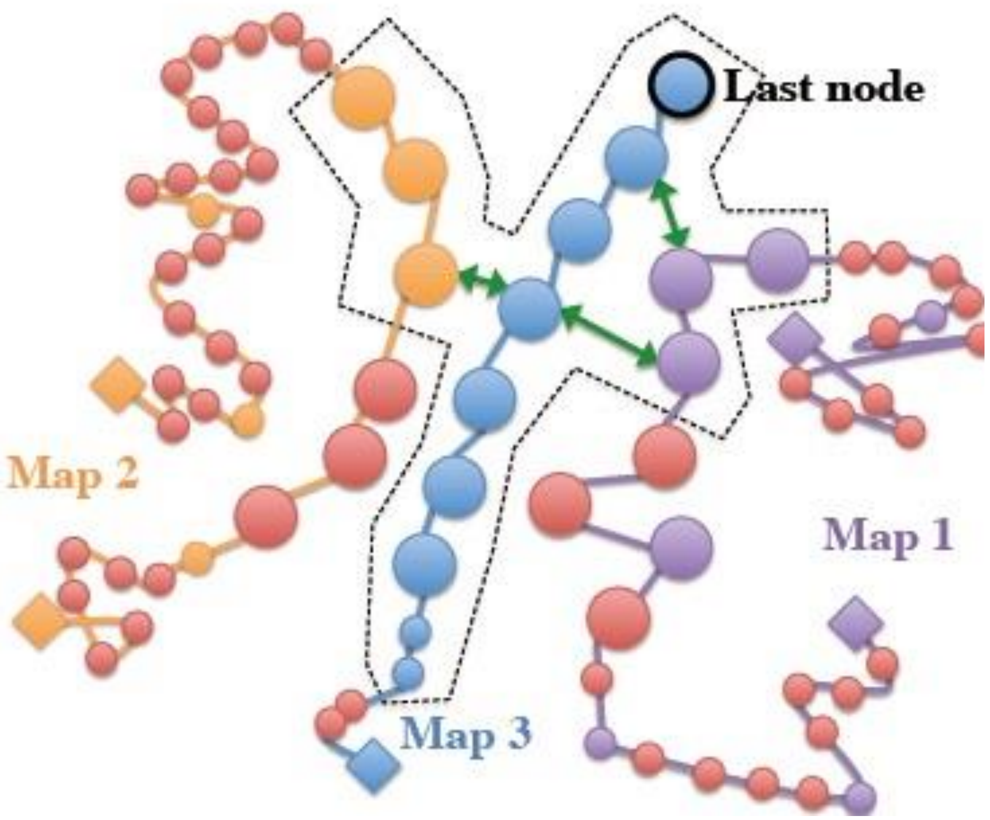
- A graph-based slam used for Kinect and stereo cameras.
- References:
  - http://introlab.github.io/rtabmap/
  - M. Labb and F. Michaud, “Online global loop closure detection for large-scale multi-session graph-based slam,” Intelligent Robots and Systems (IROS 2014), 2014 IEEE/RSJ International Conference on, Sept 2014, pp. 2661–2666.
  - Kulich M., Lhotský V., Přeučil L., “Practical Aspects of Autonomous Exploration with a Kinect2 sensor,” CoRR abs/1707.09808(2017).

Approach

- Data structure of a map: Nodes and links
  - Nodes save odometry poses for each location. Nodes also contain visualization information like laser scans, RGB images, depth image, and SURF visual words (features) used for loop closure detection.
  - There are two types of links: neighbor and loop closure.
- Approach:
  - 1. Loop closure detection: use a bayesian filter (Threshold Y=0.11, inliers>=5) to evaluate loop closure hypotheses.

    similarity=Npair/max(Nzt,Nzc)
  - 2. Graph Optimization: TORO (Tree based netwORk Optimizer)
  - 3. Memory management for online multi-session mapping

Memory management



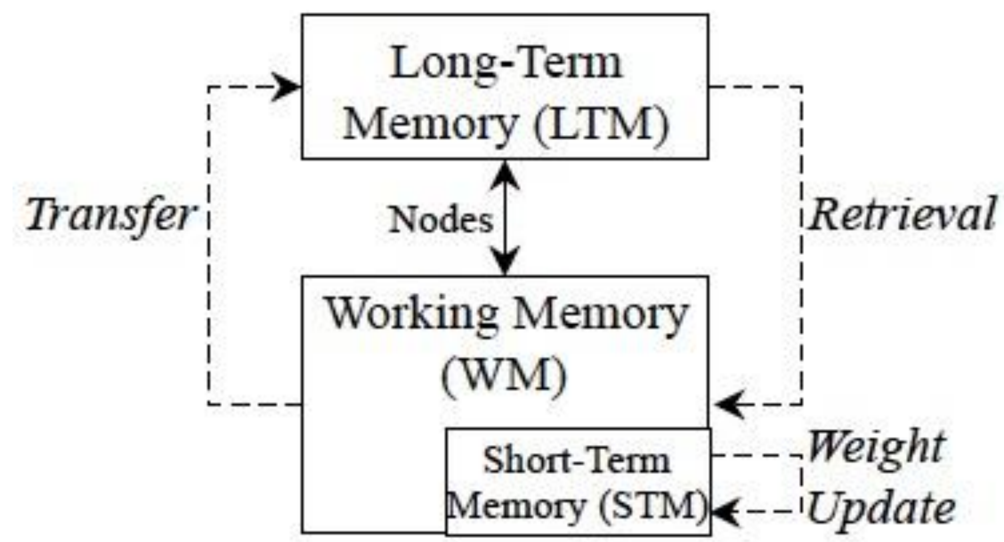


Fig. 1. Memory management model.

- The new locations (nodes) are saved in STM (eg., S=10).
- The oldest node in STM is moved to WM to detect loop closure.
- WM kept those highly weighted nodes. Old maps were sent to LTM (hard disk).
- The neighbors of the nodes in WM can be transferred back from LTM to WM for loop closure detection.
- WM has a fixed time limit T which keep the memory size constant. When the time required to process the new node reaches T, some nodes will be transferred to LTM.

Experiments

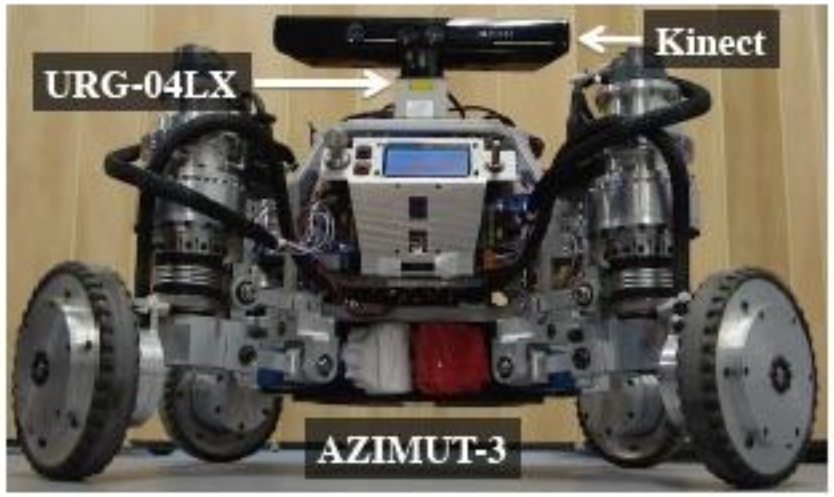


Fig. 3. AZIMUT-3 robot equipped with a URG-04XL laser range finder and a Kinect sensor.

- The robot carried a laser rangefinder and a Kinect sensor.
- RGB images are used for loop closure detection while depth images are used to find the 3D position of the visual words.
- The laser scans were used to refine the loop closure transformation, using 2D ICP.
- minimum inliers I=5, STM size S=10, Hypothesis threshold H=0.11, similarity threshold Y=0.45, T=0.7
- Five mapping sessions were conducted (total 750m) in the building.
- MacBook Pro 2010: 2.66GHz Intel Core i7 and SSD hard drive (on which STM is saved)

Experiment I

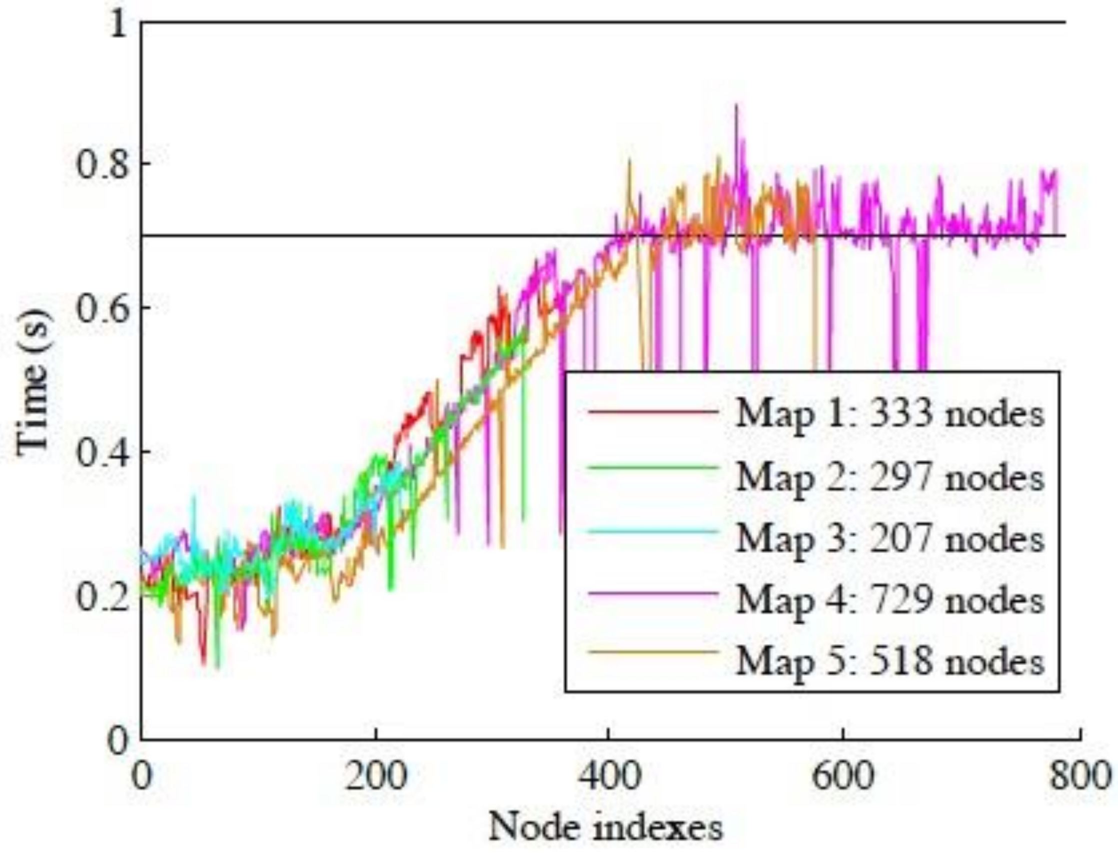


Fig. 6. Processing time in relation to the number of nodes processed over time for each data set. T is shown as a the horizontal line.

Experiment I

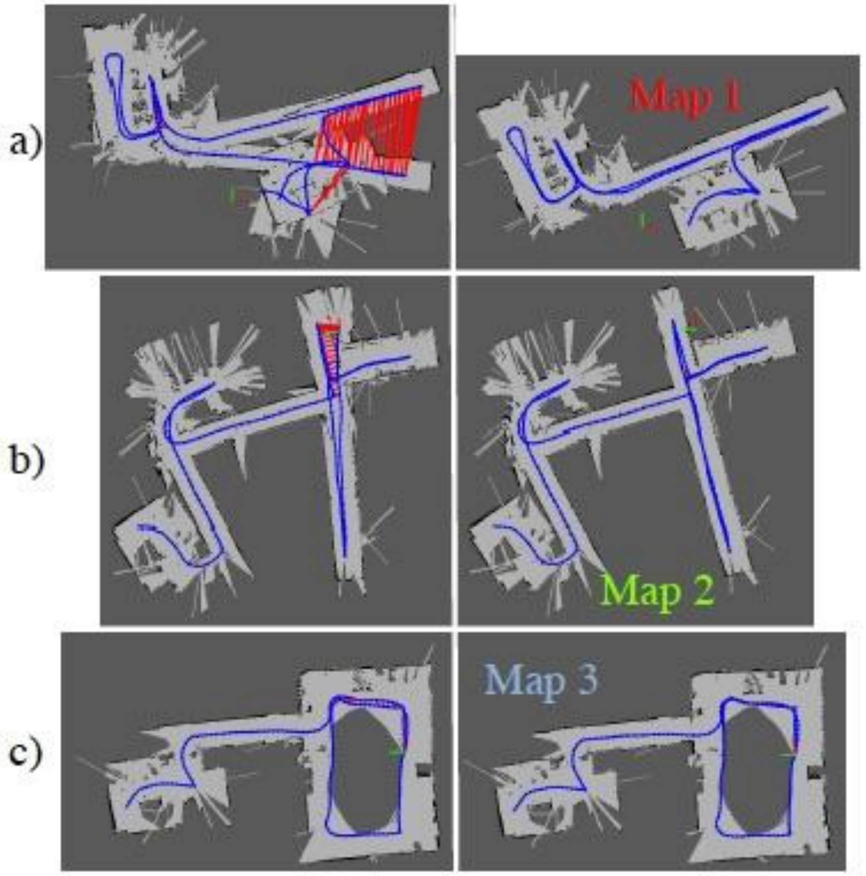


Fig. 4. Resulting local maps without (left) and with (right) graph optimizations for a) Map 1, b) Map 2 and c) Map 3. Loop closures are shown in red.

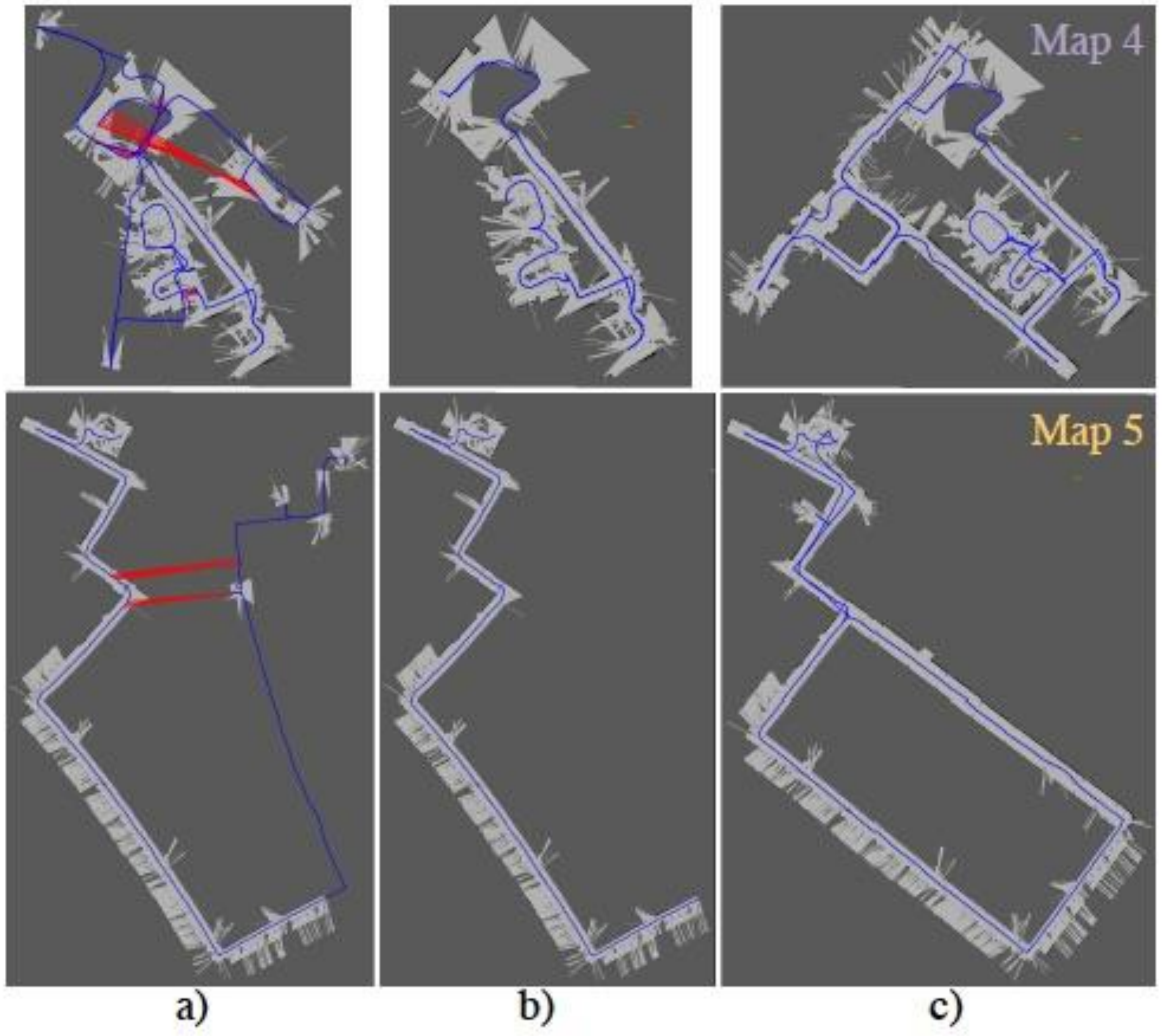


Fig. 5. Results for Map 4 (top) and Map 5 (bottom), with a) the map from all nodes still in WM (light gray) with the global graph (blue line) not optimized, b) the local map with local graph optimization and c) the global map with global graph optimization. Loop closures are shown in red.

Experiment II

- The map formed with intra-session and inter-session loop closure

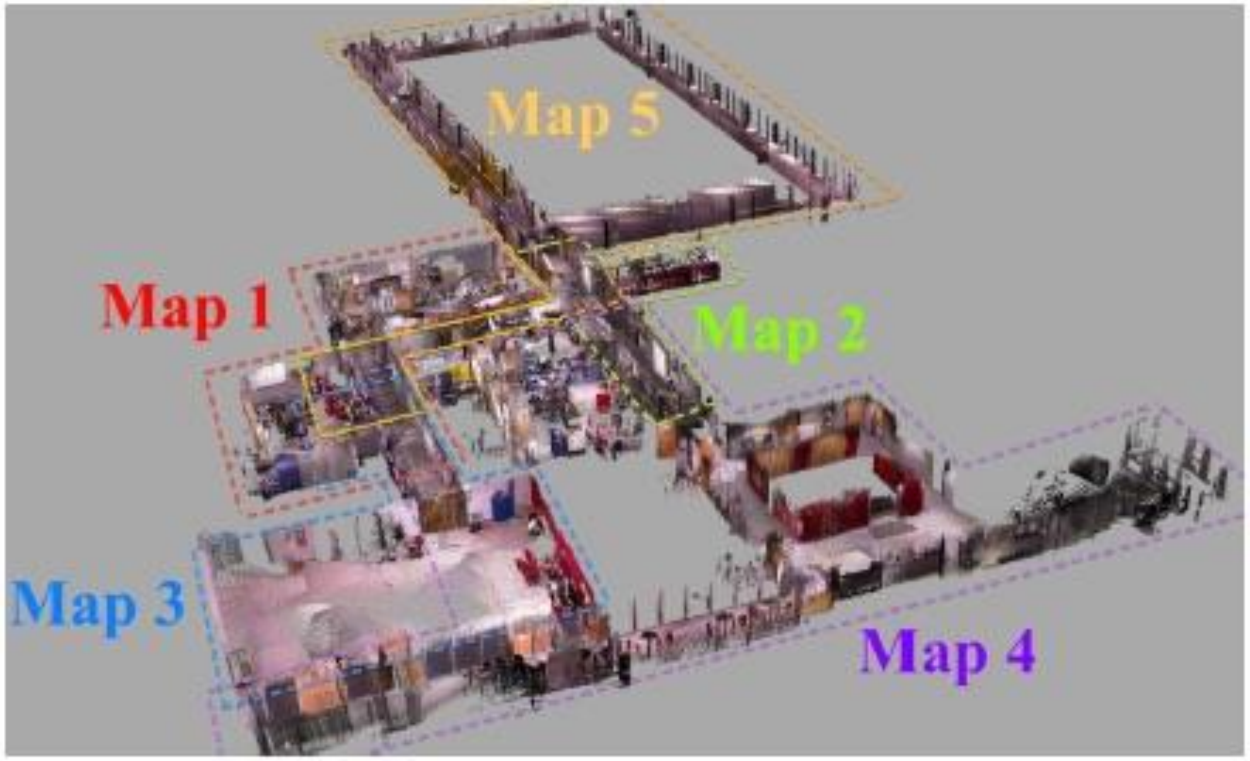


Fig. 9. Five online mapping sessions merged together automatically.

Experiment II

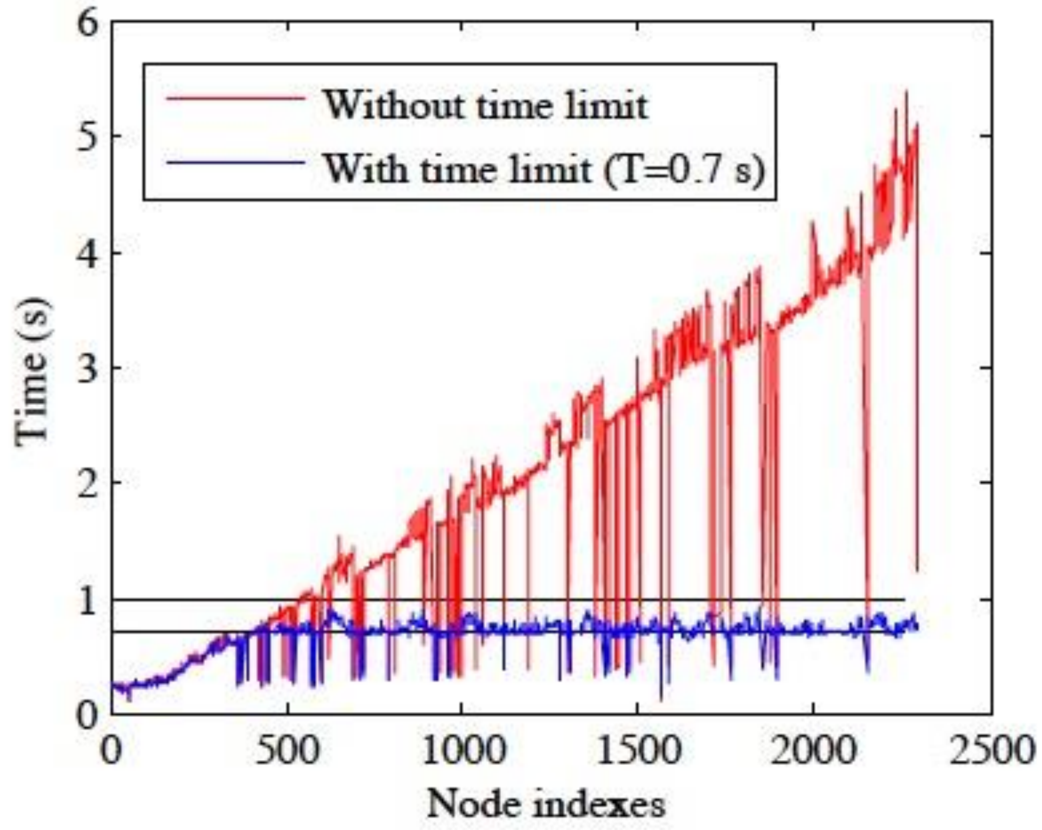


Fig. 12. Processing time for each node added to graph. The horizontal lines are $T = 0.7$ and $R = 1$.

Experiment II

Fig. 11. Global maps with (blue) and without (red) T. The maps are manually superimposed over the actual plan of the building.

- Map 5 is not correctly aligned for both condition. Few loop closure makes it difficult to correct angular errors.

Discussion

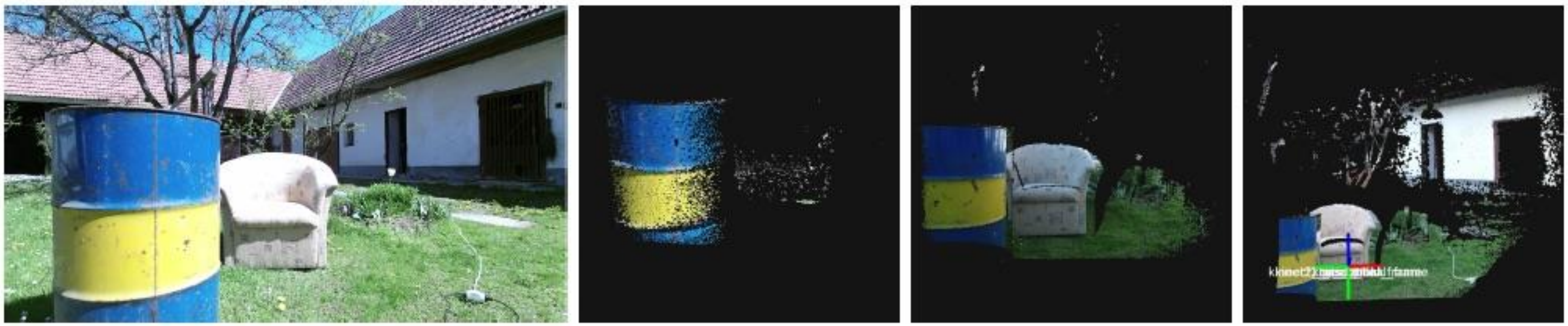
- Some nodes from the old maps have to be kept in the WM. Old maps could be easily forgotten if all nodes of the previous maps are transferred to LTM.
- Invalid loop closures could be detected: “Robust loop closing graph SLAM”

- Kulich M., Lhotský V., Přeučil L., “Practical Aspects of Autonomous Exploration with a Kinect2 sensor,” CoRR abs/1707.09808(2017).

Rgbdslam v2 [6]	RTAB-Map [3]	ORB-SLAM 2 [7]
- Very slow updates of the map	Faster than Rgbdslam, slower than ORB-SLAM but provides a fast visual odometry	+ Very fast updates of the map
+ Can re-localize after looking at known position	Problems with re-localization, but it can use the wheel odometry	+ Can successfully re-localize after being lost for a long time, but also becomes lost more often than the others
+ Well readable map, also published through ROS	+ Well readable map, also published through ROS	- The map is not very readable (for people)
+ All important data is published through ROS topics	+ All important data is published through ROS topics & services	- No data is published through ROS topics
	+ Can utilize the odometry provided by the ER1 robot	
+ Wide range of parameters	+ Wide range of parameters	- Low range of parameters

TABLE I: Comparison of RGBD SLAM libraries.

- Kulich M., etc., 2017



(a) (b) (c) (d)

Fig. 2: (a) The reference environment, (b) Kinect 2 data in a sunny day, (c) data with most of the scene covered in a shadow (d) data in the evening

The first experiment(Fig. 2b) was done in a very bright sunlight at 1 PM. The range of Kinect: 1.2-1.4m, generally.
The same area is also scanned later afternoon when the most of the scene is covered in shadow from the building, but the sunlight is still bright so even areas covered in shadow are illuminated, see Fig. 2c. The range: 3.5-6m.
The last experiment was done in the evening when the scene illumination is much lower, see Fig. 2d. The range: 12m.

SURF feature