

# ARO Homework: Simultaneous Localization and Mapping (SLAM) using Iterative Closest Point (ICP)

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March 13, 2019

The task is to finish implementation of a ROS node for simultaneous localization and mapping (SLAM) using the iterative closest point (ICP) algorithm on 2D laser scans (point clouds). Use this source archive as a starting point. It contains the following catkin packages:

- **aro\_slam** The ICP SLAM package to finish.
- **transforms3d** A third-party library for conversion between various transformation representations.
- **point\_cloud\_color** A library for conversion of laser scans to point clouds, with compensation of robot movement.
- **voxel\_map** A library for volumetric mapping, needed for building the occupancy grid.

Namely, implement function **icp** within module **aro\_slam.icp**, `aro_slam/src/aro_slam/icp.py`, and get familiar with the node calling the *icp* function, `aro_slam/scripts/icp_slam_2d`. Implement the function according to its documentation and the following lecture slides:

- ICP algorithm (partially covers [1]),
- absolute orientation ( $\operatorname{argmin}_{\mathbf{R} \in \text{SO}(3), \mathbf{t} \in \mathbb{R}^3} \sum_i \|\mathbf{R}\mathbf{p}_i + \mathbf{t} - \mathbf{q}_i\|^2$ ; covers [2]).

Implement the outlier rejection (line 3 in the ICP algorithm) as follows. Let  $\mathcal{C} = \{(\mathbf{p}_i, \mathbf{q}_i)\}_i$  be the set of correspondences from the nearest neighbor search (from line 2),  $i \in \{1, \dots, N\}$ , and  $d_i$  the distance between corresponding points,  $d_i = \|\mathbf{p}_i - \mathbf{q}_i\|$ . Construct the set of inlier correspondences  $\mathcal{C}'$  to be used in optimization of  $\mathbf{R}, \mathbf{t}$  (at line 4):

$$\mathcal{C}' = \{(\mathbf{p}_i, \mathbf{q}_i) \mid d_i \leq rQ_d(p)\},$$

using  $p$ -quantile of the distances  $d_i$ ,  $Q_d(p)$ , and a multiplier  $r$ . Corresponding parameters of the *icp* functions are `inlier_ratio = p`, `inlier_dist_mult = r`.

To test the whole ICP SLAM node, you can use the following launch files:

```
roslaunch aro_slam bag.launch
roslaunch aro_slam bag.launch with_odom:=0
roslaunch aro_slam live.launch
```

I encourage you to test the *icp* function separately before the overall SLAM test.

## References

- [1] Y. Chen and G. Medioni, "Object modelling by registration of multiple range images," *Image and Vision Computing*, vol. 10, no. 3, pp. 145–155, 1992. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/026288569290066C>
- [2] K. Arun, T. S. Huang, and S. D. Blostein, "Least-squares fitting of two 3-d point sets," *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, vol. PAMI-9, no. 5, pp. 698–700, 1987.