

Graph-based SLAM on Normal Distributions Transform Occupancy Map

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Recent advances in Normal distributions transform occupancy map (NDT-OM) representation have proven to be a viable option for mapping static as well as dynamic environments. Scan registration methods, which use NDT maps offer fast and reliable way of registering two laser scans.

In this work, we combine 2D NDT mapping and scan matching with the graph-based representation of simultaneous localization and mapping (SLAM). This novel approach uses NDT mini-maps for partial map storage inside the pose graph nodes. It also includes fast incremental scan matcher for odometry estimation. The scan matcher allows to create larger mini-maps which offer better loop closure validation. This work also presents a novel robust distribution to distribution (D2D)-NDT scan matching. It is used for loop closure registration and validation of correct matches.

The implementation can operate as an online algorithm inside the Robot Operating System (ROS) framework. The algorithm was tested on MIT Stata Center datasets.

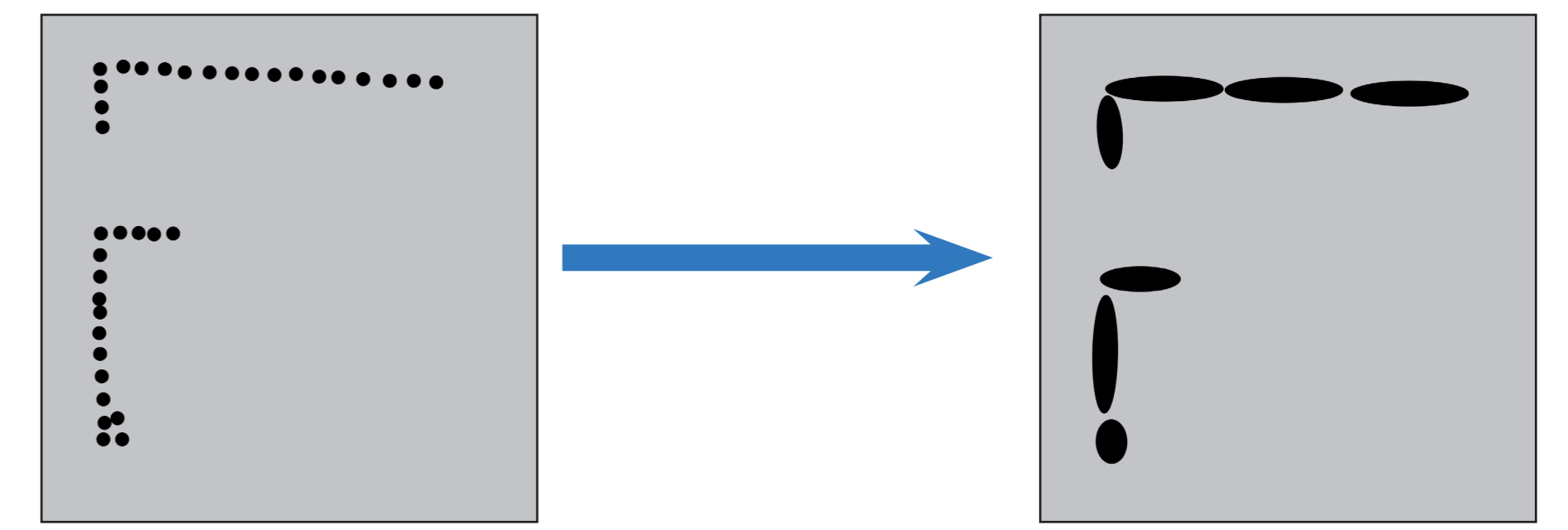
Overview of Algorithm

- Builds upon knowledge in NDT registration
- Creates a map of unknown environment
- Localizes a robot based on created map
- Produces easily integratable package in ROS

Benefits

- No need for initial guess from odometry
- Local map with fast refresh time
- Precise global map for path planning
- Runs in a real time
- Novel Robust D2D registration algorithm

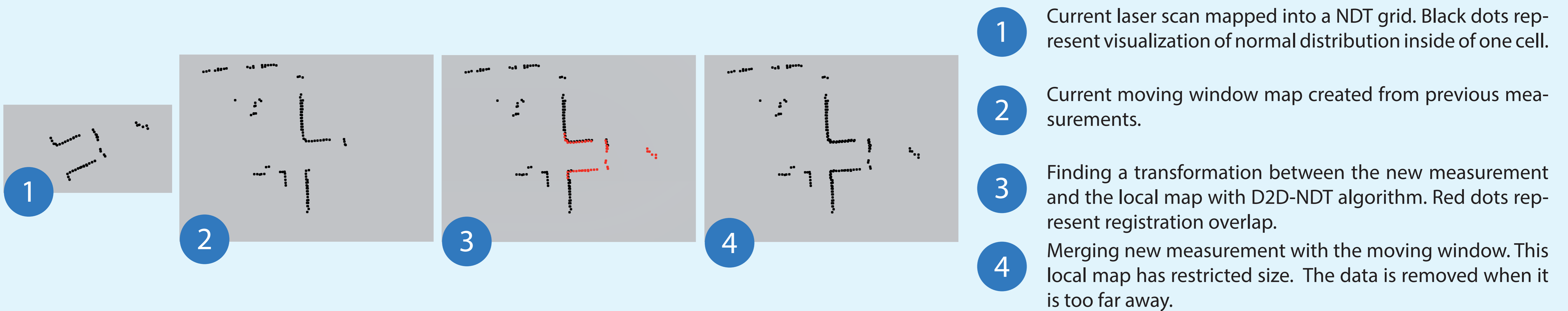
NDT



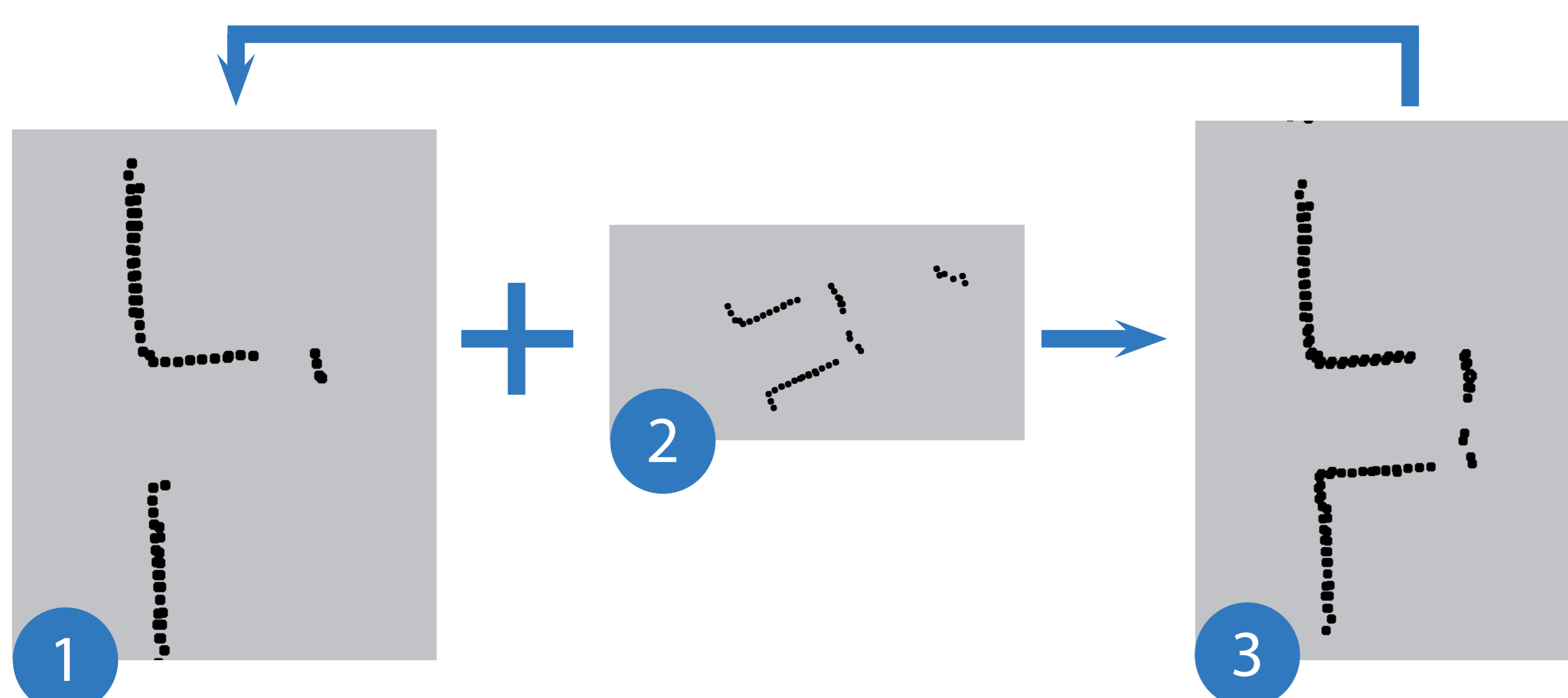
Normal distributions transform (NDT) is a special type of a grid representation. Its central idea is to map a point cloud from laser scanner into a grid. Each cell contains normal distribution calculated from all points mapped into this field.

- + Continuous representation inside of a cell, coarser grid
- + Lower memory consumption over long time
- + Precise registration algorithms (e.g. D2D-NDT)

1. Incremental Scan-matching in the Moving Window

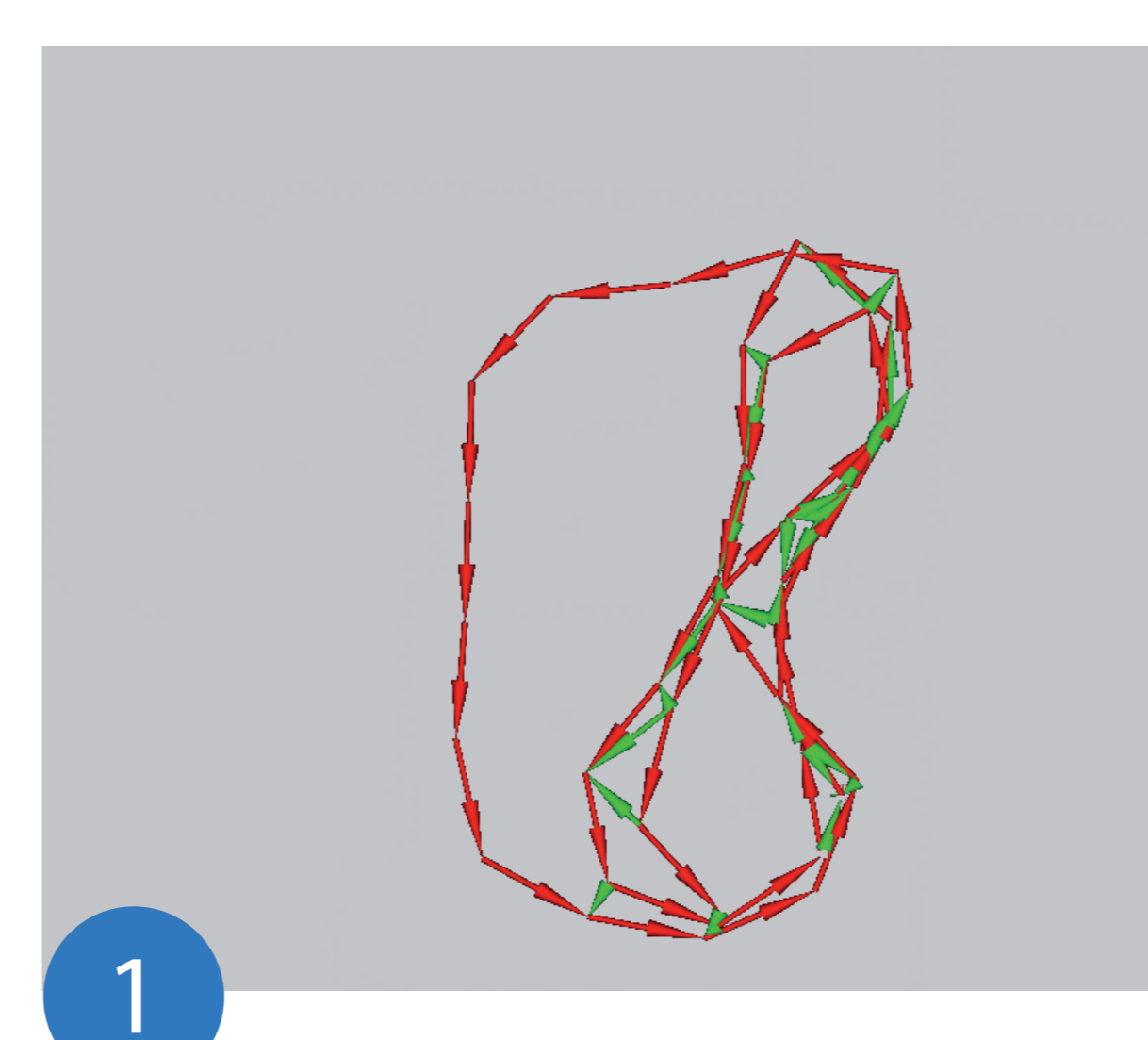


2. NDT Frame Creation



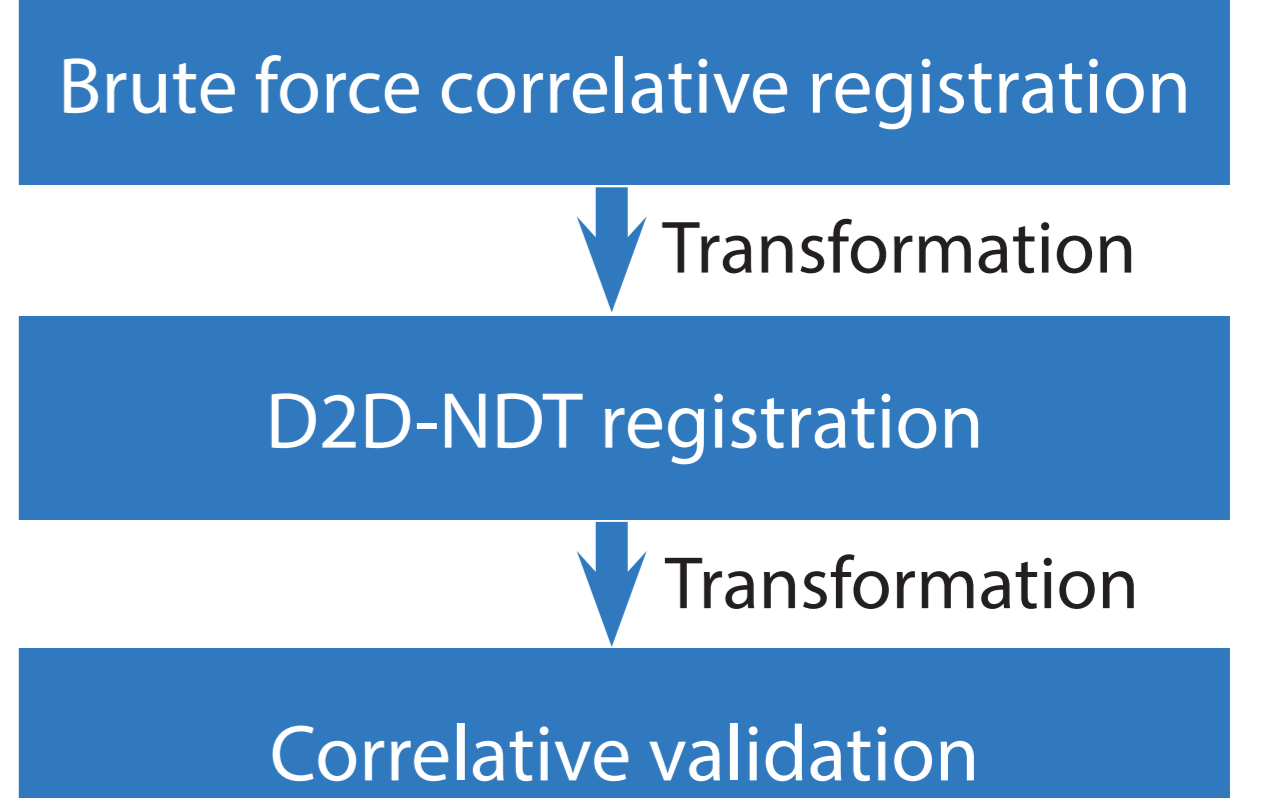
The transformation from the incremental scan-matching is used to overlap the new measurement (2) with small buffered local map (1) called NDT frame. The process is repeated with every laser measurement. The process is stopped when the robot moves certain euclidean distance. The accumulated NDT frame is inserted into a node of the pose graph and the algorithm starts again with an empty frame.

3. Pose Graph + Loop Closure



The NDT frame from the last step is inserted into a pose graph (1). The pose graph consists of nodes which carry information about current possible position of the robot. Red edges represent transformation between two nodes which comes from the NDT frame creation process. Green edges represent loop closures which are obtained by registering with my novel Robust D2D scan matching. This algorithm does not require any initial guess. The whole graph is corrected with the least square optimization. The result of this operation restructures the graph to the most likely configuration.

Robust D2D registration



4. Global Map

The resulting global map is created by overlapping all NDT frames based on transformation taken from nodes in the pose graph. This makes the map correct even after a long run with many loops when the local moving window might be already corrupted by error accumulation.

Figures on the right show the results of NDT-GSLAM in comparison to other two well known SLAM algorithm implemented in the ROS. The black dots represent walls and a gray and white color represents unoccupied space.

