Albert-Ludwigs-Universität Freiburg, Institut für Informatik
PD Dr. Cyrill Stachniss
Lecture: Robot Mapping
Winter term 2013

Sheet 10

Topic: Graph-Based SLAM

Submission deadline: February 3 (Task 1), February 10 (Task 2)
Submit to: `robotmappingtutors@informatik.uni-freiburg.de`

Exercise: Graph-Based SLAM

Implement a least-squares method to address SLAM in its graph-based formulation. To support this task, we provide a small *Octave* framework (see course website). The framework contains the following folders:

data contains several datasets, each gives the measurements of one SLAM problem

octave contains the Octave framework with stubs to complete.

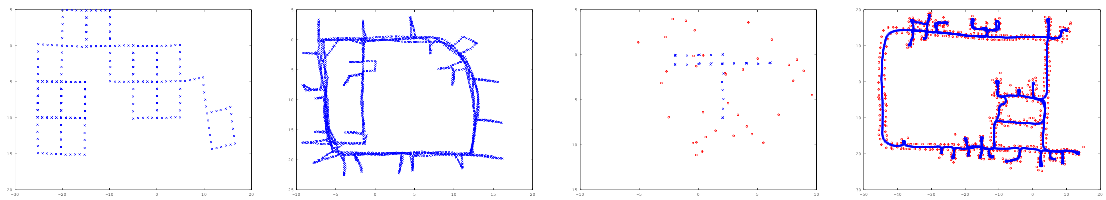
plots this folder is used to store images.

The below mentioned tasks should be implemented inside the framework in the directory `octave` by completing the stubs:

1.
   - Implement the function in `compute_global_error.m` for computing the current error value for a graph with constraints.
   - Implement the function in `linearize_pose_pose_constraint.m` for computing the error and the Jacobian of a pose-pose constraint. Test your implementation with `test_jacobian_pose_pose`.
   - Implement the function in `linearize_pose_landmark_constraint.m` for computing the error and the Jacobian of a pose-landmark constraint. Test your implementation with `test_jacobian_pose_landmark`.

2.
   - Implement the function in `linearize_and_solve.m` for constructing and solving the linear approximation.
   - Implement the update of the state vector and the stopping criterion in `lsSLAM.m`. A possible choice for the stopping criterion is $\|\Delta\mathbf{x}\|_\infty < \epsilon$, i.e., $\|\Delta\mathbf{x}\|_\infty = \max(|\Delta x_1|, \ldots, |\Delta x_n|) < \epsilon$.

After implementing the missing parts, you can run the framework. To do that, change into the directory octave and launch *Octave*. To start the main loop, type `lsSLAM`. The script will produce a plot showing the positions of the robot and (if



simulation-pose-pose | intel | simulation-pose-landmark | dlr

Figure 1: Result for each dataset.

available) the positions of the landmarks in each iteration. These plots will be saved in the `plots` directory.

Figure 1 depicts the result that you should obtain after convergence for each dataset. Additionally, the initial and the final error for each dataset should be approximately:

dataset	initial error	final error
simulation-pose-pose.dat	138862234	8269
intel.dat	1795139	360
simulation-pose-landmark.dat	3030	474
dlr.dat	369655336	56860

The state vector contains the following entities:

- pose of the robot: $\mathbf{x}_i = (x_i \; y_i \; \theta_i)^T$
  Hint: You may use the function v2t$(\cdot)$ and t2v$(\cdot)$:

$$\text{v2t}(\mathbf{x}_i) = \begin{pmatrix} R_i & \mathbf{t}_i \\ \mathbf{0} & 1 \end{pmatrix} = \begin{pmatrix} \cos(\theta_i) & -\sin(\theta_i) & x_i \\ \sin(\theta_i) & \cos(\theta_i) & y_i \\ 0 & 0 & 1 \end{pmatrix} = X_i$$

$$\text{t2v}(X_i) = \mathbf{x}_i$$

- position of a landmark: $\mathbf{x}_l = (x_l \; y_l)^T$

We consider the following error functions:

- pose-pose constraint: $\mathbf{e}_{ij} = \text{t2v}(Z_{ij}^{-1}(X_i^{-1}X_j))$, where $Z_{ij} = \text{v2t}(\mathbf{z}_{ij})$ is the transformation matrix of the measurement $\mathbf{z}_{ij}^T = (\mathbf{t}_{ij}^T, \theta_{ij})$.
  Hint: For computing the Jacobian, write the error function with rotation matrices and translation vectors:

$$\mathbf{e}_{ij} = \begin{pmatrix} R_{ij}^T(R_i^T(\mathbf{t}_j - \mathbf{t}_i) - \mathbf{t}_{ij}) \\ \theta_j - \theta_i - \theta_{ij} \end{pmatrix}$$

- pose-landmark constraint: $\mathbf{e}_{il} = R_i^T(\mathbf{x}_l - \mathbf{t}_i) - \mathbf{z}_{il}$