CS284: Simultaneous Localization and Mapping

Homework 2, Fall Semester 2021

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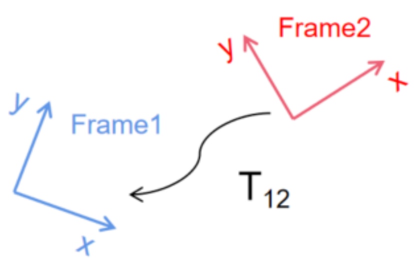
- Deadline: **23:59, 20th of October 2021** (please submit a zip via email to TA)
- **Please reread our policies on academic integrity. It is a very serious matter, and any violations will be prosecuted to the fullest extend.**

Task Description

Homework 2 is about pose graph optimization and consists of three sub-tasks. The setting is similar to homework 1, and we again have a robot that is moving on a circular trajectory of 1m radius. In this homework, the relative pose estimations are already given, and your task will be to optimize the overall trajectory of the robot. The robot measures one scan every 30 degrees and makes a full turn, which is why there are 13 poses and 12 relative pose measurements (the last frame is at an identical position than the first one). The data is given to you in the form of a 3x12 matrix of relative poses in which each column is given by the parameters $(\Delta x, \Delta y, \Delta \theta)^T$) that define the relative transformation between adjacent frames (column 1 is the transformation between frame 1 and 2 etc.). The definition of the relative pose is shown in Figure 1. The parameters are added in the below form to a transformation matrix that then can help to transform points from the next to the previous frame.

- Task 1: Complete dead reckoning using the relative poses. You may assume that the first frame has identity rotation and zero translation. Remember the rule for updating the absolute pose, which is $T_i = T_{i-1} \cdot T_{i-1,i}$. What can you observe? In particular, is there anything to say about the thirteenth pose?



$$T_{12} = \begin{bmatrix} cos(\Delta\theta_{12}) & -\sin(\Delta\theta_{12}) & \Delta x_{12} \\ \sin(\Delta\theta_{12}) & cos(\Delta\theta_{12}) & \Delta y_{12} \\ 0 & 0 & 1 \end{bmatrix}$$

Figure 1 : Definition of relative pose.

- Task 2: Now drop the last frame and interpret the final relative pose (i.e. column 12) as the geometrically verified relative pose between the 12th and the first frame (found through loop closure), i.e. $T_{12,1}$. The relative pose constraints may be considered as edges in a graph where each node corresponds to one of the absolute poses (the newly added edge is illustrated in orange in the Figure below).

Use pose graph optimization to optimize the absolute poses. Describe your observations.

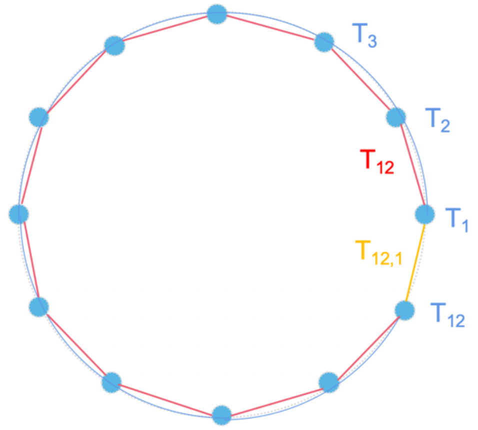


Figure 2 : Constraints between adjacent frames.

- Task 3 : As illustrated by the green edges in Figure 3, we now add 10 additional edges to the graph (between every two frames). There are now a total of 12 nodes (each one representing a 2D absolute pose with 3 parameters), and 22 edges in the graph. Do the pose graph optimization one more time. Describe your observations.

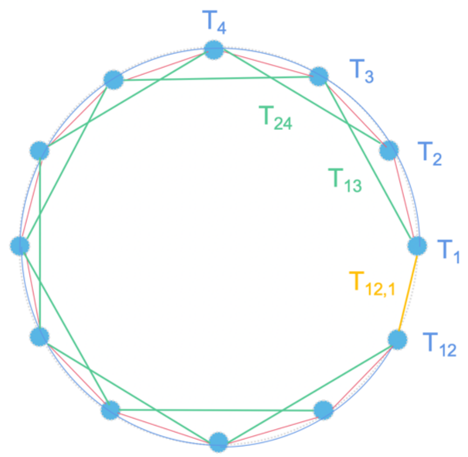


Figure 3 : Constraints between every two frames.

- Task 4 (Bonus): Visualize and explain what the information matrix looks like.

Submission

Please submit a PDF report (not more than 3 pages!) along with the code to the TA email address before the deadline (put professor in CC). Your code and results should be the same with what you submitted in the email, then arrange for a time with the TA to demonstrate your code. Your report must include:

- A description of your implementation. This should cover a basic description of the algorithm. It should also include the physical structure of the program (i.e. file description, dependencies), and instructions on how to compile and use it (i.e. how to interpret the result).

- Visualization of the reconstructed trajectory on 3 tasks. Comparison of the results before and after optimization.
- Observations on the performance of your algorithm, both in terms of efficiency and in terms of accuracy.
- Qualitative observations on the results.

Please use ”SLAM HW2 – Your name” as the email-header when sending the email. Please pack all the files into a zip file, the structure should be:

[Your name] folder

– Your name.pdf

– [code] folder