Project Rawseeds

Relative Pose Error (RPE)

recommended performance measure

Note: what follows is based on the concepts defined by the document "General concepts and definitions for BPs", which is part of the information associated to all Benchmark Problem instances. Please refer to that document for clarification.

Introduction

The relative pose error is a recommended measure for comparing the results of a SLAM algorithm. Recommended measure means that its computation is encouraged but is not necessary for a Benchmark Solution.

The relative pose error measures the accuracy of a SLAM result by comparing the relative transformation between nearby poses estimated by the algorithm to the true relative transformations. By considering only relative transformations and not absolute poses in a global reference frame, the relative pose error does not measure the accumulated error of the robot's trajectory. Therefore, the relative pose error can be regarded as complementary to the absolute trajectory error, which explicitly accounts for the error accumulation.

Creation of a Benchmark Solution

A benchmark solution using the relative pose error is computed as follows:

1. For every mutual visible pair of poses $< x_i^{GT}, x_j^{GT} >$ the relative transformation $x_{i,j}^{GT} = x_j^{GT} \ominus x_i^{GT}$ has to be computed/measured. Here, $\ominus$ is the inverse of the standard motion composition operator and thus $x_{i,j}^{GT} = x_j^{GT} \ominus x_i^{GT}$ is the relative transformation that moves the pose x_i^{GT} onto x_j^{GT}. In detail,

   $$\Delta x_{ij}^{GT} = -\cos(\theta_i^{GT})\, x_i^{GT} - \sin(\theta_i^{GT})\, y_i^{GT} + x_j^{GT}$$

   $$\Delta y_{ij}^{GT} = \sin(\theta_i^{GT})\, x_i^{GT} - \cos(\theta_i^{GT})\, y_i^{GT} + y_j^{GT}$$

   $$\Delta \theta_{ij}^{GT} = (-\theta_i^{GT} + \theta_j^{GT}) \bmod 2\pi$$

2. The following list of the true relative transformations $x_{i,j}^{GT}$ has to be provided:
   1. As a text file using the *comma-separated values* (csv) format.
   2. Each line must have the form:

      $< timestamp_i,\ timestamp_j,\ \Delta x_{ij}^{GT},\ \Delta y_{ij}^{GT},\ \Delta \theta_{ij}^{GT} >$ where $timestamp_i$ is the time instant t_i (as specified by the poseGT) and $timestamp_j$ respectively. The values Δx_{ij}^{GT}, Δy_{ij}^{GT}, $\Delta \theta_{ij}^{GT}$ are computed according to the standard motion composition operator, as shown above.

Evaluation of a SLAM Algorithm by Applying a Benchmark Solution using the Relative Pose Error

There are no preparatory operations required such as the alignment of the reconstructed map of the environment to the mappingGT or similar. It only requires to compute the *relative transformations* according to the estimate of the SLAM algorithm:

1. For each pair of poses $< x_i, x_j >$ for which an entry in Benchmark Solution with timestamp_i and timestamp_j exists, compute $x_{i,j} = x_j \ominus x_i$
   equivalent to the computation shown above.
2. Compute the difference in the relative displacement $d_{ij} = x_{ij} \ominus x_{ij}^{GT}$ (according to the formula shown above).
3. The translational and rotational relative pose error is then given by T-RPE = $\frac{1}{N}\sum_{ij}(trans(d_{ij}))^2$ and R-RPE = $\frac{1}{N}\sum_{ij}(rot(d_{ij}))^2$, where N is the overall number of pairs in the benchmark solution used for the computation of relative pose error. The functions trans() and rot() refer to the first two and the third component of d_{ij} respectively.

Information to be Provided when Creating a Benchmark Solution

Whenever a Benchmark Solution includes RPE, it is also required to include the following information:

- The text file according to the specifications given above.
- A description how the true relative transformations (x_{ij}^{GT}) are obtained (e.g., a highly accurate measurement device, manual alignment, or similar).
- If an interpolation is used to compute the pose between the true relative transformations, a full description of this interpolation method has to be provided. The description has to be detailed and precise to let any technically competent reader replicate the described process.