Online Variational Bayesian Motion Averaging

Guillaume Bourmaud

Toshiba Research Europe
Computer Vision Group
Introduction

Motion averaging (aka pose-graph inference for $G = SE(3)$)

Given noisy relative transformations
\[
\{Z_{mn} \in G\}_{1 \leq m < n \leq N}
\]

Estimate absolute transformations
\[
\{T_{iW} \in G\}_{i = 1, \ldots, N}
\]

Example of application: RGB-D mapping

RGB-D camera

Visual Odometry

$Z_{(k-1)k}$

Online Motion Averaging

$Z_{mk}$

Loop closure detection

$\{T_{iW}\}_{i = 1, \ldots, k}$

Aligned depth maps
Contributions

To perform **online motion averaging on large scale problems**, we propose an algorithm that is:

1. **Computationally efficient**: process the measurements one by one

2. **Memory efficient**: approximate the posterior distribution of the absolute transformations with a number of parameters that grows at most linearly over time

3. **Robust**: detect and remove wrong loop closures
Our approach

The absolute transformations can be reparametrized as follows:

\[ T_{i(i+1)} = T_{iW} T_{(i+1)W}^{-1} \]

<table>
<thead>
<tr>
<th></th>
<th>Absolute</th>
<th>Relative</th>
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<tbody>
<tr>
<td>Estimated transformations</td>
<td>{T_{iW}}_{i=1,\ldots,k}</td>
<td>{T_{i(i+1)}}_{i=1,\ldots,k-1}</td>
</tr>
<tr>
<td>at time instant (k)</td>
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Case of a single loop:

\[
\arg\min_{\{T_{i(i+1)}\}_{i=1,\ldots,k-1}} \left\| \log_G \left( Z_{1N}^{-1} \prod_{i=1}^{N-1} T_{i(i+1)} \right) \right\|^2_{\Sigma_{1N}} + \sum_{i=1}^{N-1} \left\| \log_G \left( Z_{i(i+1)}^{-1} T_{i(i+1)} \right) \right\|^2_{\Sigma_{i(i+1)}}
\]

loop closure

odometry
Our approach cont’d

Case of a single loop:

The relative parametrization induces very small correlations!

Motivation for a variational Bayesian approximation of the posterior distribution assuming independent relative transformations (see paper)
Results

$G = \text{Sim}(3)$: Monocular Visual SLAM, sequence KITTI 13

Ground truth (Lidar)  Visual Odometry  COP-SLAM  Ours

$G = \text{SE}(3)$: RGB-D Mapping

Visual Odometry  Ours