Merging Partially Consistent Maps

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Outline

• Considerations about Map Learning

• Map Merging

• State of the Art & Limitations

• Our Approach

• Experiments
Map Learning – Theory

• SLAM[1][2] = estimating map of an environment and trajectory of a sensing platform

• Small environments → trivial

• Large environments → scalable up to city-sized areas

Map Learning – Practice

• Data must be acquired in single runs

• For large environments, multiple mapping sessions are needed

• Environments change … remap?

• Errors in the map … remap?
Map Learning – Considerations

• Acquiring good data is an error prone task!

• The operator must have a deep knowledge of:
  • Platform – sensors – environment – algorithms

• Difficult to obtain the \textbf{perfect} map $\rightarrow$ several sub-optimal maps
  • Is there a way to use them?
Map Merging

• Combine existing sub-maps into a single map
State Of The Art

• Mostly done using image registration techniques [3][4]

• Main approach:
  • Extract lines from input maps
  • Find the rigid transformation that maximizes the overlap

• Intuitive and effective if maps are clean

• What if maps are affected by noise?

Limitations

- Problems to converge in presence of high errors/distortions

- Works only for 2D case
Our Approach

• Main Assumption:
  • Maps are deformable bodies

• Key Idea:
  • Take two maps, deform one on the other
  • … starting from a given initial guess
Map Representation

- A map is a deformable network consisting of
  - Nodes: robot poses/local maps
  - Edges: transforms between nearby nodes

- Edges can be seen as springs connecting nodes
Map Deformation

- Perturbing the springs, we can deform the network
- Deforming the network, we can reduce the residual noise
Deformation Algorithm

- Start from the initial guess
- Data associations among graphs [5][6]
- Insert inter-graph edges
- LSE optimization
- Iterate on neighbors

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Grid-Map to Pose Graph

- Extract the Voronoi diagram
- Down-sample and connect neighboring points
- Synthesize observation ray-casting points to the obstacles
Raw Data Experiments

• Understand the applicability to a practical scenario
Raw Data Experiments – Voronoi

INPUT

VORONOI POSE GRAPH

REAL POSE GRAPH
Raw Data Experiments

- Our approach against single rigid transformations
- Measure the entropy of the reconstructed map

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Single Rigid Transformation</th>
<th>Graph-Based Map Merging</th>
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</thead>
<tbody>
<tr>
<td>Dis-Basement-Small</td>
<td>2039.99</td>
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<td>UBremen-Real</td>
<td>3436.44</td>
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Synthetic Experiments

- Characterize the performance of the method, varying parameters

INPUT

OUTPUT RIGID TRANSFORMATION

OUR OUTPUT
Synthetic Experiments

- Compare our solution and single rigid transformations against the ground truth
- Measure the error at increasing levels of gaussian noise

<table>
<thead>
<tr>
<th>Translational error [x, y] (m)</th>
<th>Rotational error (deg)</th>
<th>Rigid Transformation ATE</th>
<th>Deformable Bodies ATE</th>
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<tbody>
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23/10/2014
Conclusions & Future Works

- Simple and efficient map merging approach
  - Deform inputs to reduce residual error
  - Agnostic to data association procedure

- Future Directions:
  - 3D map merging
  - Map Updating
References


