GraphSLAM

Pieter Abbeel
UC Berkeley EECS
Graph-based Formulation

- Use a **graph** to represent the problem
- **Every node** in the graph **corresponds to a pose** of the robot during mapping
- **Every edge** between two nodes **corresponds to the spatial constraints** between them
- **Goal**: Find a configuration of the nodes that **minimize the error** introduced by the constraints

\[
J_{\text{GraphSLAM}} = x_0^\top \Omega_0 x_0 + \sum_t (x_t - f(u_t, x_{t-1}))^\top R_t^{-1} (x_t - f(u_t, x_{t-1})) \\
+ \sum_t \sum_i (z^i_t - h(x_t, m, c^i_t))^\top Q_t^{-1} (z^i_t - h(x_t, m, c^i_t))
\]
The problem can be described by a graph.

Goal:
- Find the assignment of poses to the nodes of the graph which minimizes the negative log likelihood of the observations:

\[
p^* = \text{argmin} \sum_{ji} e_{ji}^T \Omega_{ji} e_{ji}
\]
Approaches

- 2D approaches:
  - Lu and Milios, ‘97
  - Montemerlo et al., ‘03
  - Howard et al., ‘03
  - Dellaert et al., ‘03
  - Frese and Duckett, ‘05
  - Olson et al., ‘06
  - Grisetti et al., ‘07
  - Tipaldi et al., ‘07

- 3D approaches:
  - Nuechter et al., ‘05
  - Dellaert et al., ‘05
  - Triebel et al., ‘06
  - Grisetti et al., ‘08/’09
Graph-Based SLAM in a Nutshell

- Problem described as a graph
  - Every node corresponds to a robot position and to a laser measurement
  - An edge between two nodes represents a data-dependent spatial constraint between the nodes

[KUKA Hall 22, courtesy P. Pfaff & G. Grisetti]
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[KUKA Hall 22, courtesy P. Pfaff & G. Grisetti]
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- Once we have the graph, we determine the most likely map by “moving” the nodes

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- ... like this.

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Graph-Based SLAM in a Nutshell

- Once we have the graph, we determine the most likely map by “moving” the nodes
- ... like this.
- Then we render a map based on the known poses

[KUKA Hall 22, courtesy P. Pfaff & G. Grisetti]
Graph-based Visual SLAM

[ courtesy B. Steder]
The KUKA Production Site
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### The KUKA Production Site

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Scans</td>
<td>59668</td>
</tr>
<tr>
<td>Total acquisition time</td>
<td>4,699.71 seconds</td>
</tr>
<tr>
<td>Traveled distance</td>
<td>2,587.71 meters</td>
</tr>
<tr>
<td>Total rotations</td>
<td>262.07 radians</td>
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<tr>
<td>Size</td>
<td>180 x 110 meters</td>
</tr>
<tr>
<td>Processing time</td>
<td>&lt; 30 minutes</td>
</tr>
</tbody>
</table>