GraphSLAM

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Graph-based Formulation

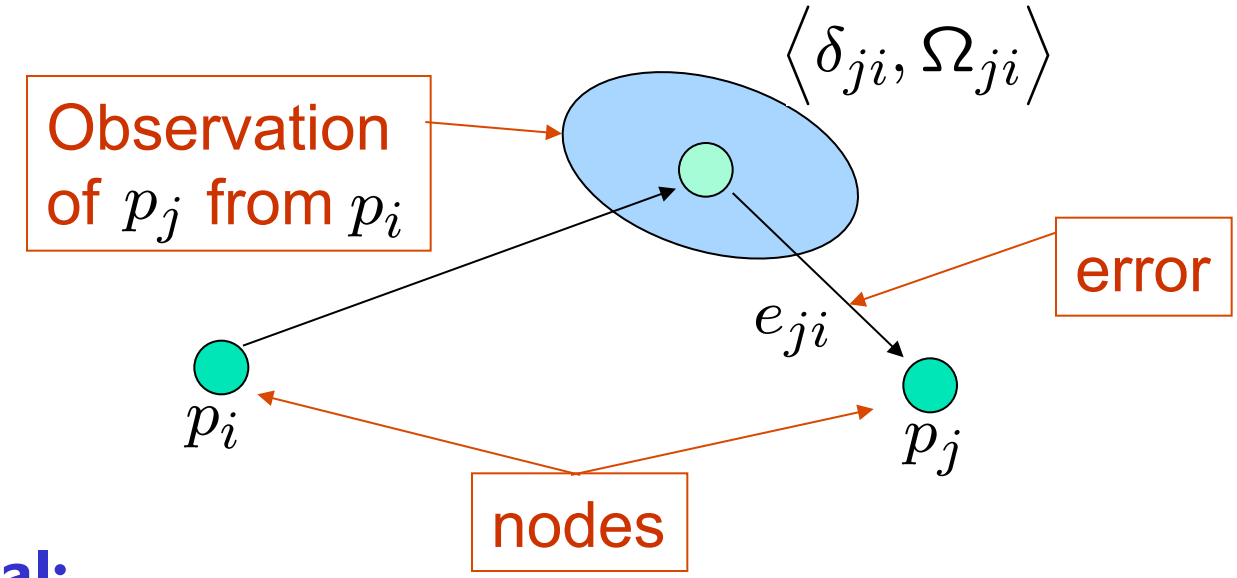
- Use a **graph** to represent the problem
- **Every node** in the graph **corresponds to a pose** of the robot during mapping
- **Every edge** between two nodes **corresponds to the spatial constraints** between them

- **Goal**:
  Find a configuration of the nodes that **minimize the error** introduced by the constraints

$$J_{\text{GraphSLAM}} = x_0^\top \Omega_0 x_0 + \sum_t (x_t - f(u_t, x_{t-1}))^\top R_t^{-1} (x_t - f(u_t, x_{t-1}))$$
$$+ \sum_t \sum_i (z_t^i - h(x_t, m, c_t^i))^\top Q_t^{-1} (z_t^i - h(x_t, m, c_t^i))$$

Problem Formulation

- 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:

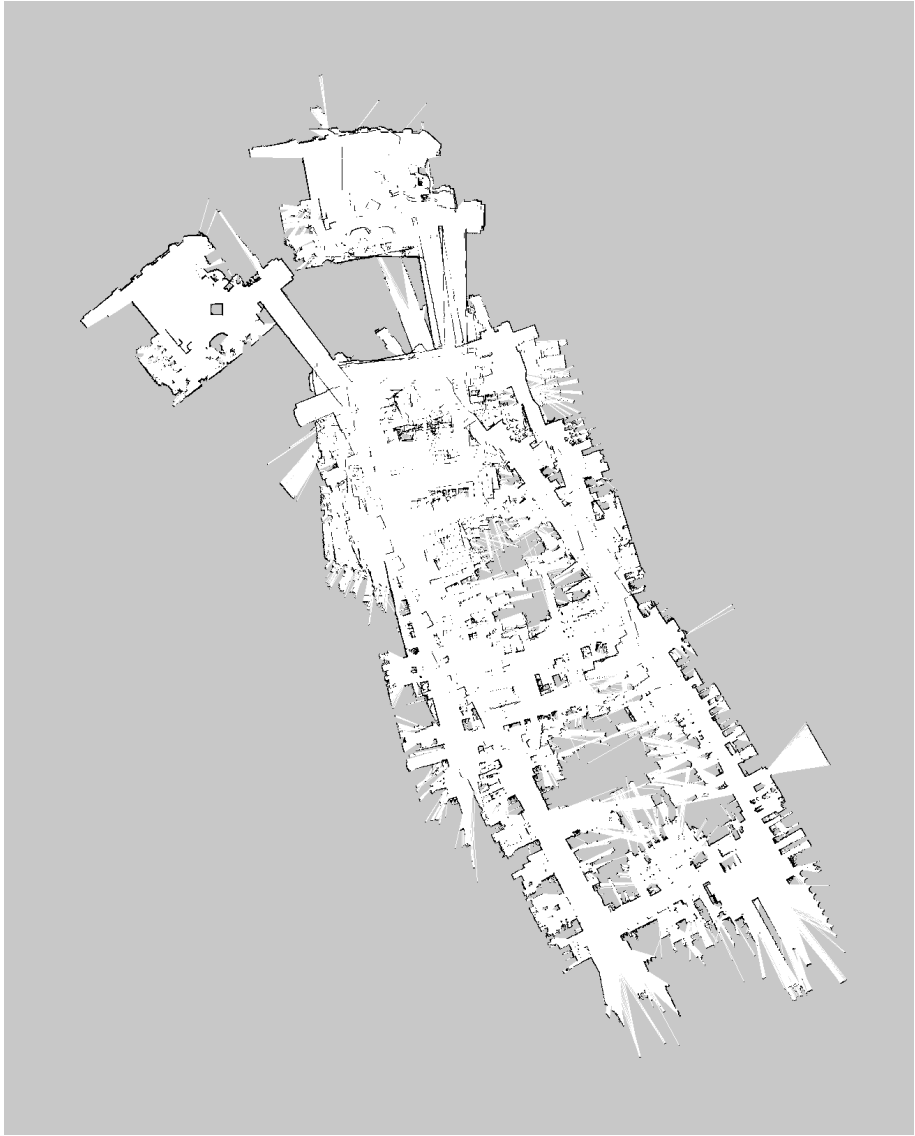
$$\mathbf{p}^* = \text{argmin} \sum_{ji} e_{ji}^T \Omega'_{ji} e_{ji}^T$$

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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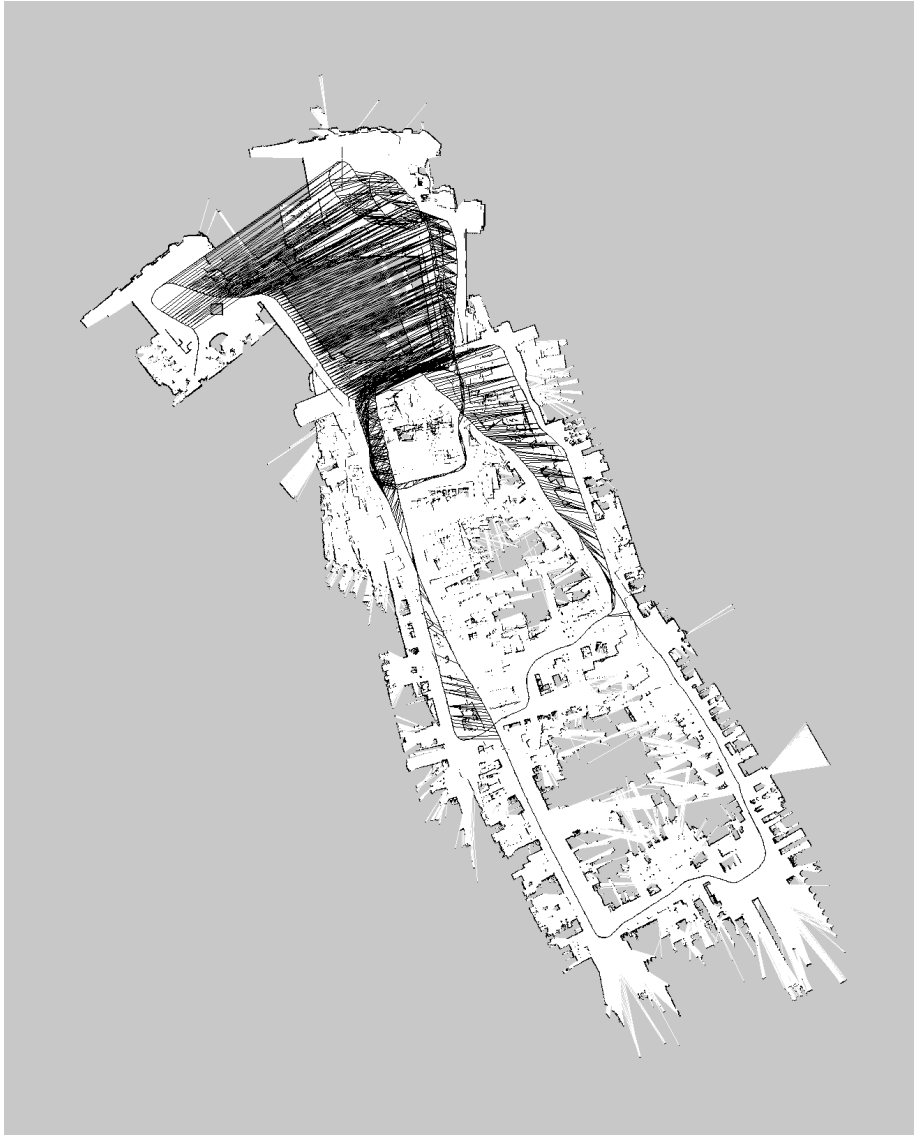

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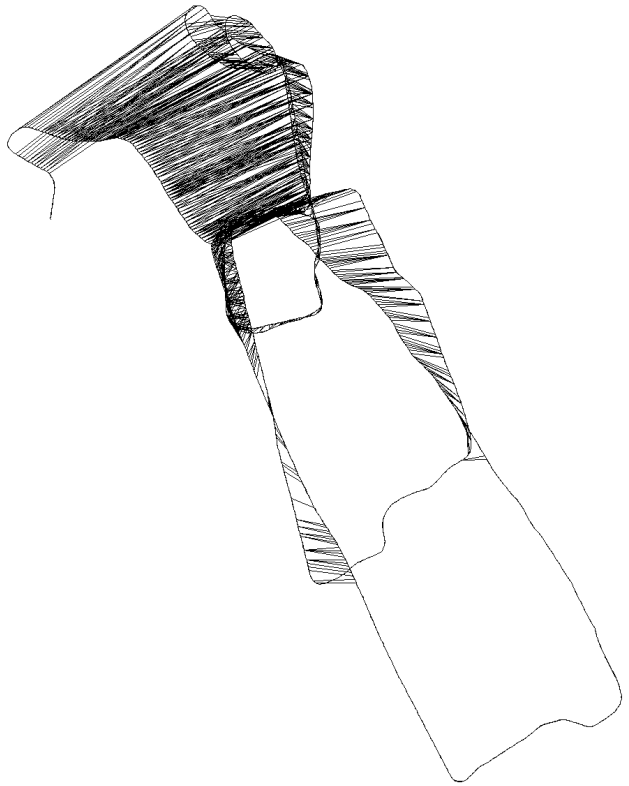
Graph-Based SLAM in a Nutshell

- Once we have the graph, we determine the most likely map by "moving" the nodes



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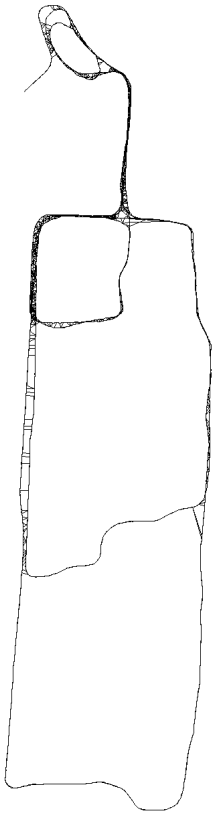
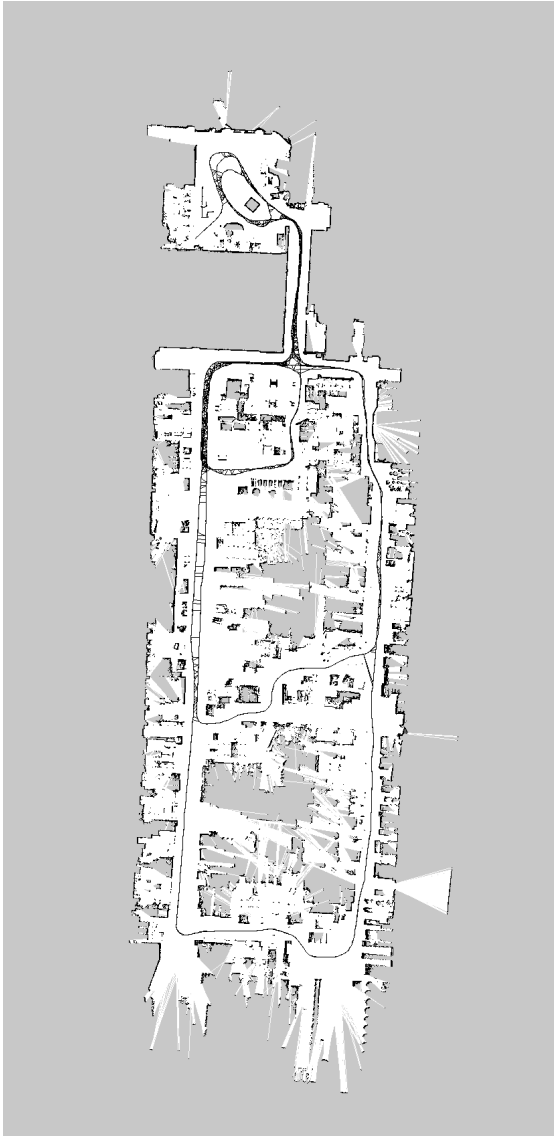


[KUKA Hall 22, courtesy P. Pfaff & G. Grisetti]

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



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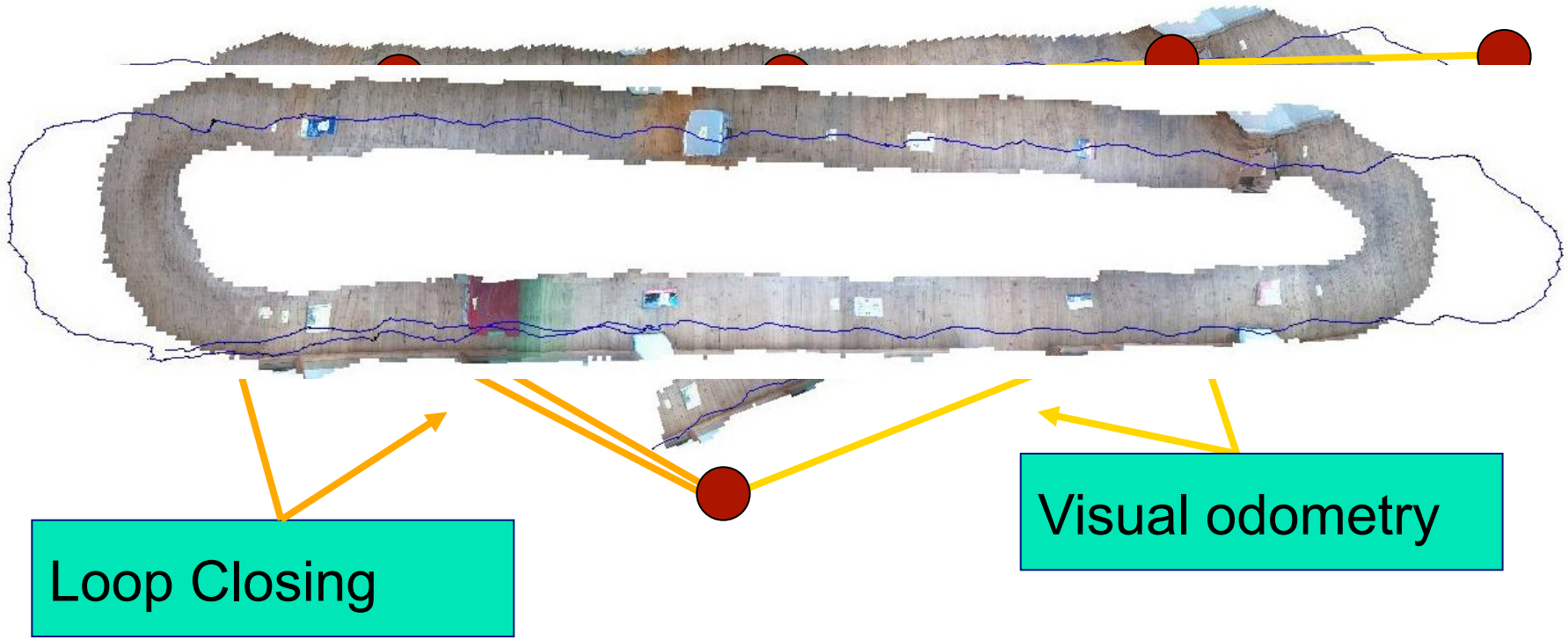
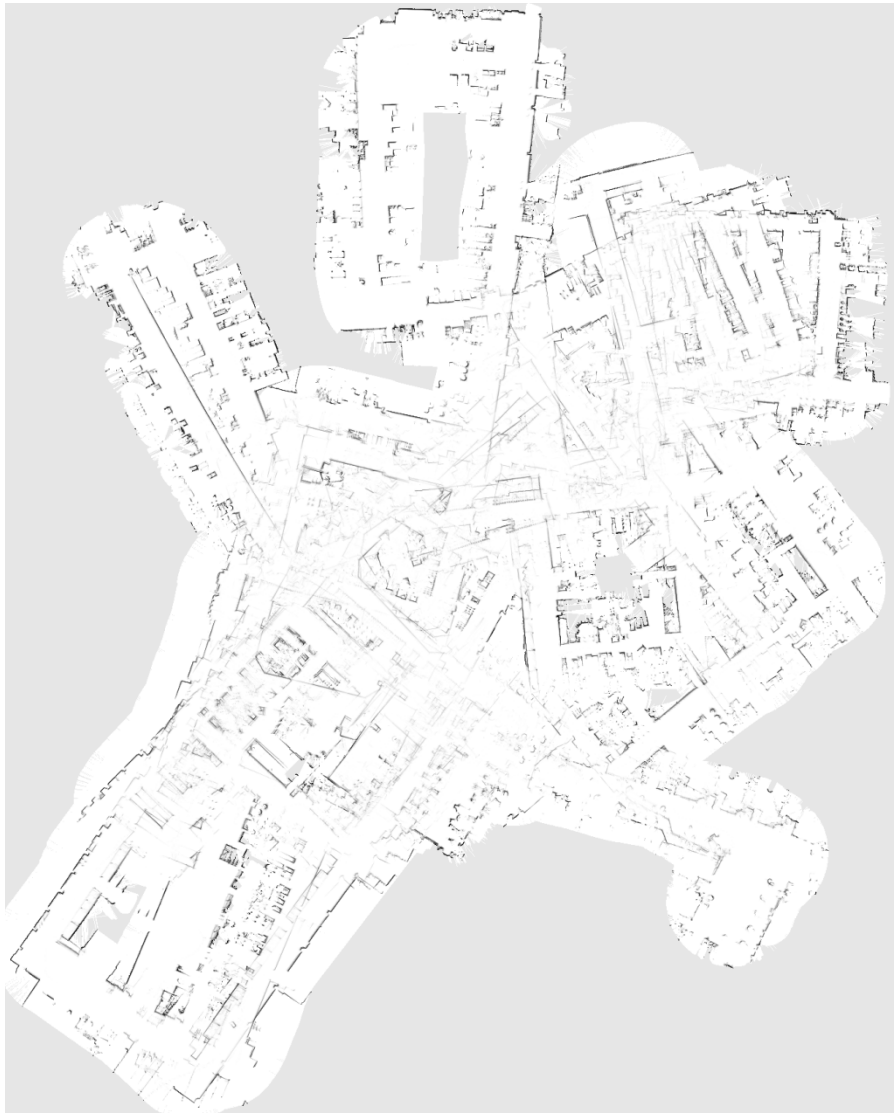
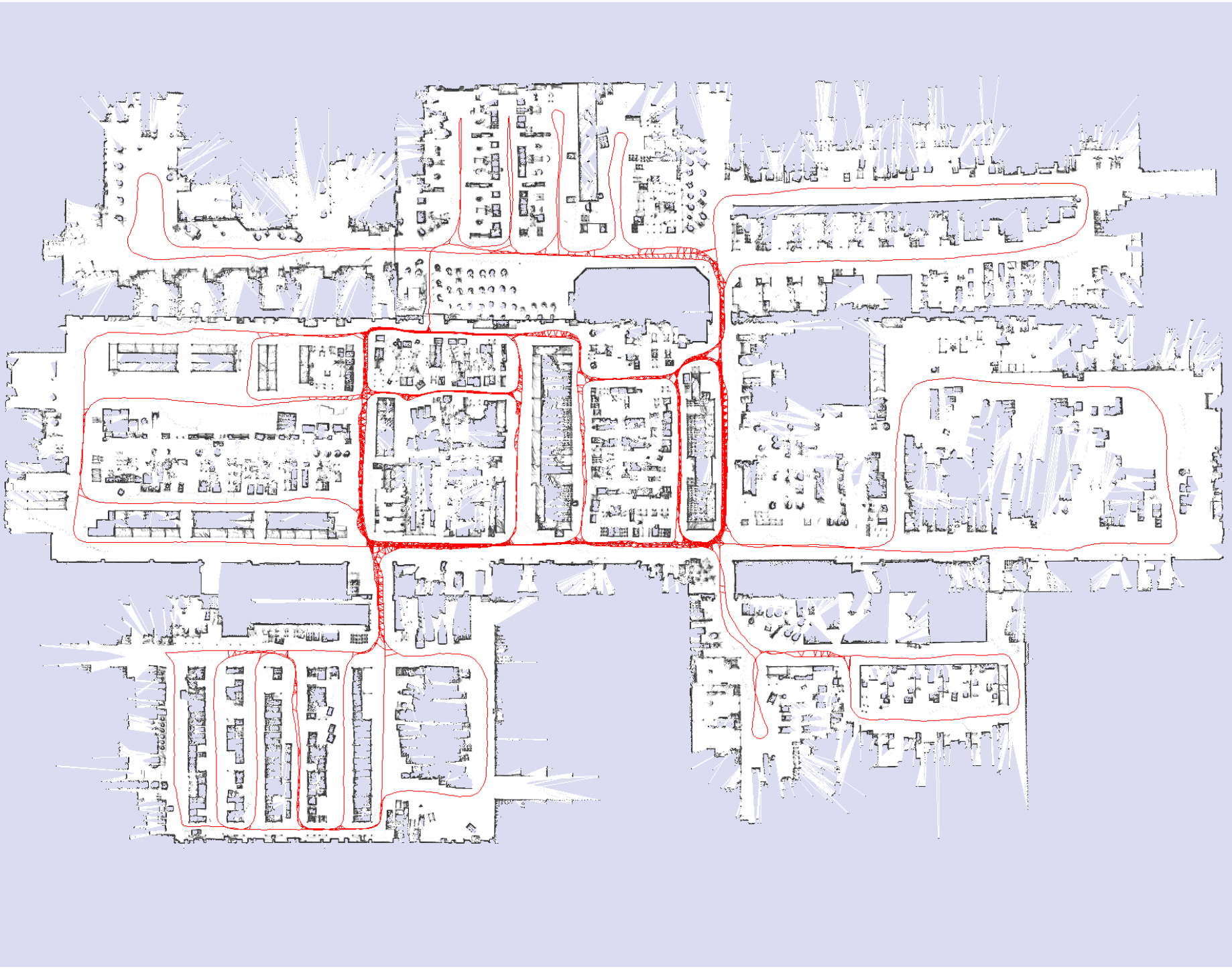
Graph-based Visual SLAM



[courtesy B. Steder]

The KUKA Production Site





The KUKA Production Site

scans	59668
total acquisition time	4,699.71 seconds
traveled distance	2,587.71 meters
total rotations	262.07 radians
size	180 x 110 meters
processing time	< 30 minutes