# GraphSLAM

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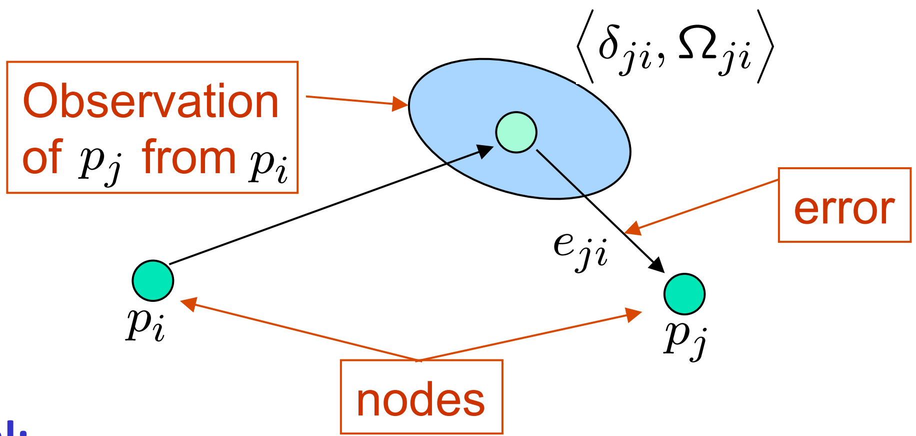
# Graph-based Formulation

- 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

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

# 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:

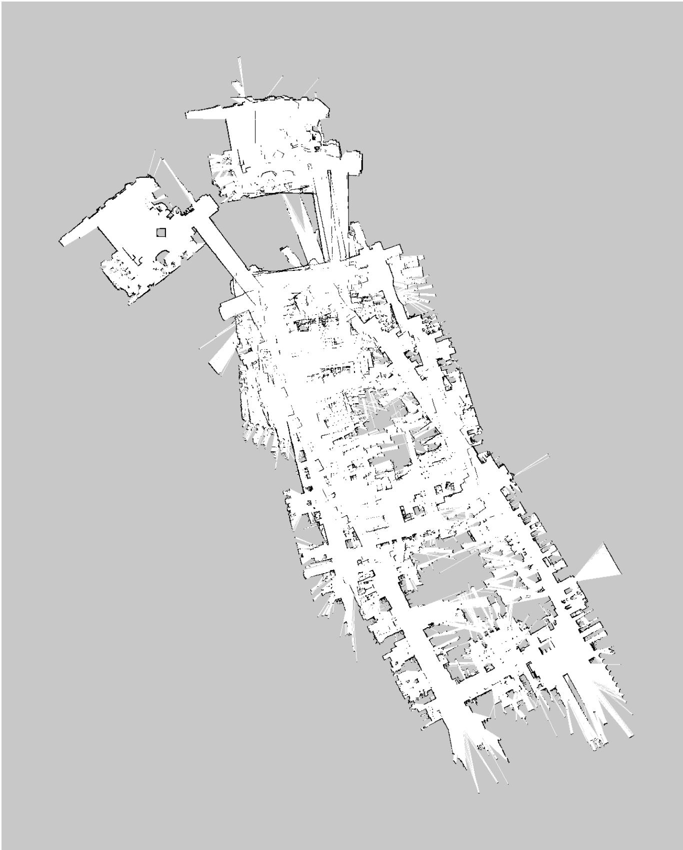
$$\mathbf{p}^* = \operatorname{argmin} \sum_{ji} e_{ji}^T \Omega'_{ji} e_{ji}^T$$

# 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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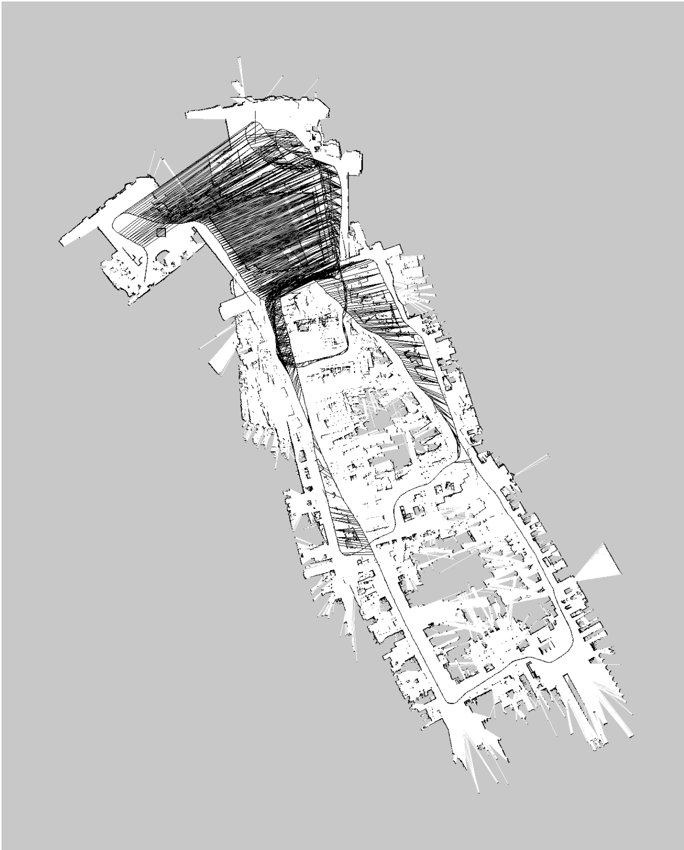

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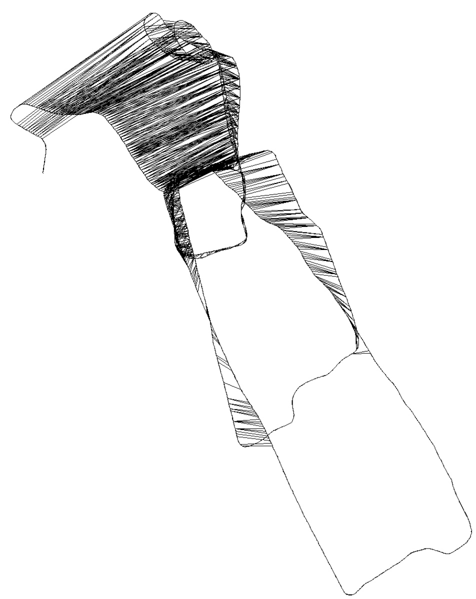
- Once we have the graph, we determine the most likely map by "moving" the nodes



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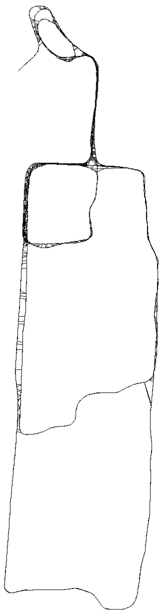
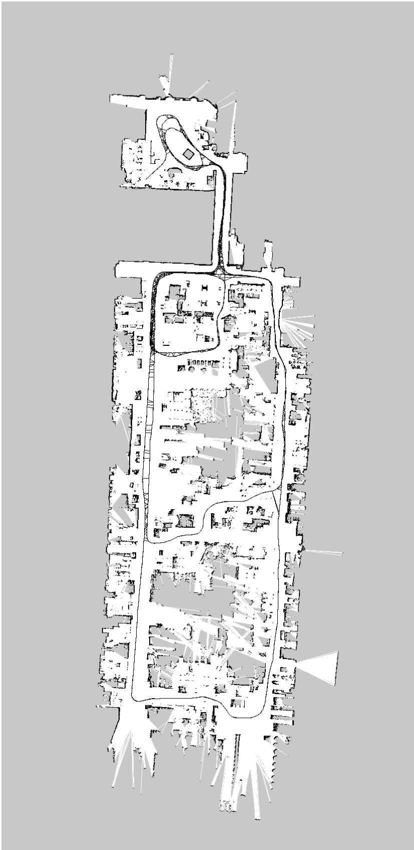
- … like this.



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

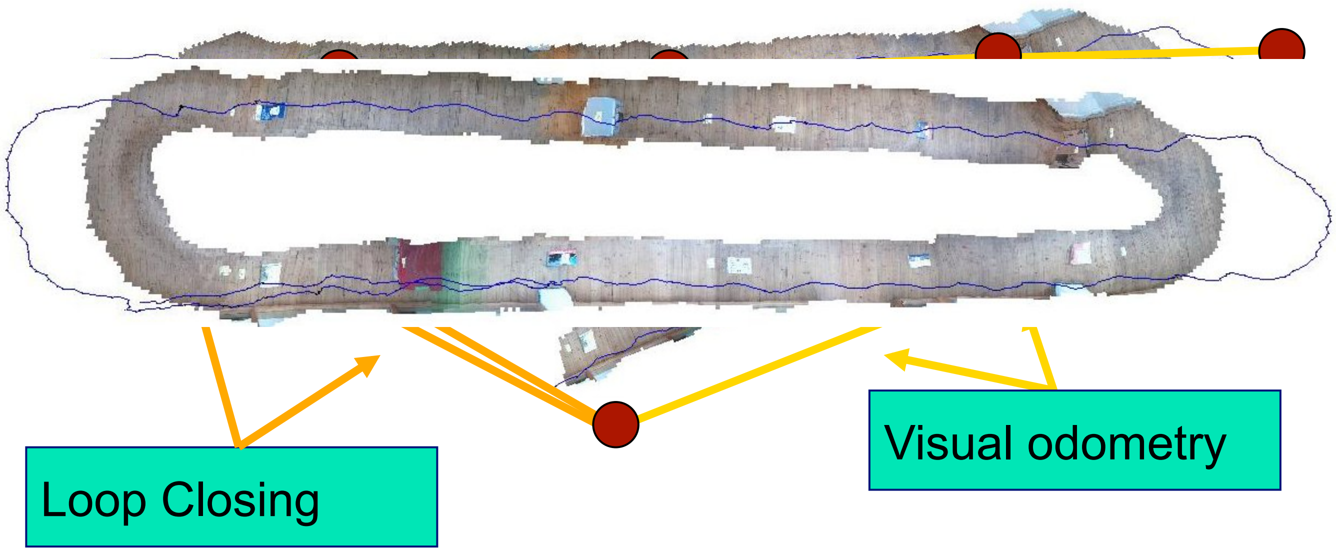
# Graph-Based SLAM in a Nutshell

- 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



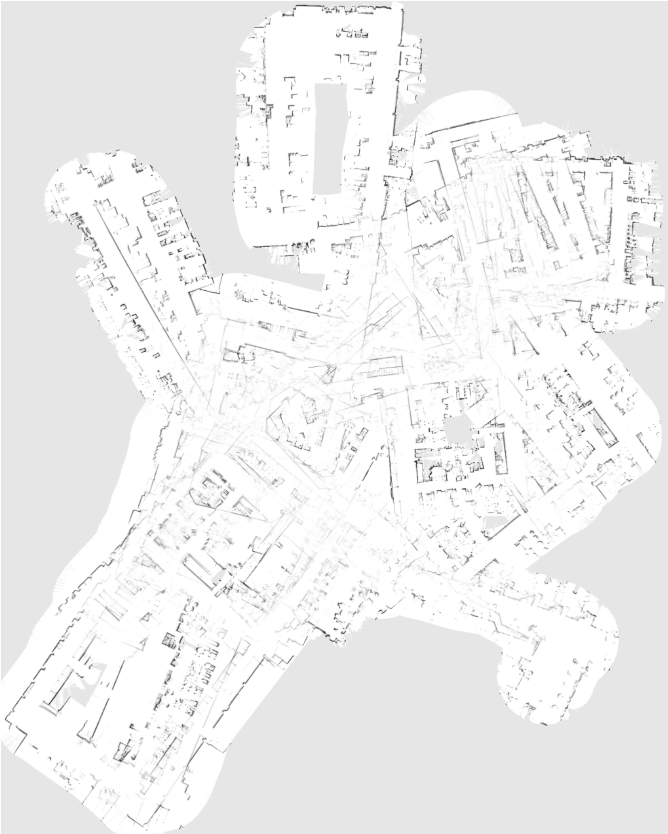
[KUKA Hall 22, courtesy P. Pfaff & G. Grisetti]

# Graph-based Visual SLAM




[ courtesy B. Steder]

# The KUKA Production Site



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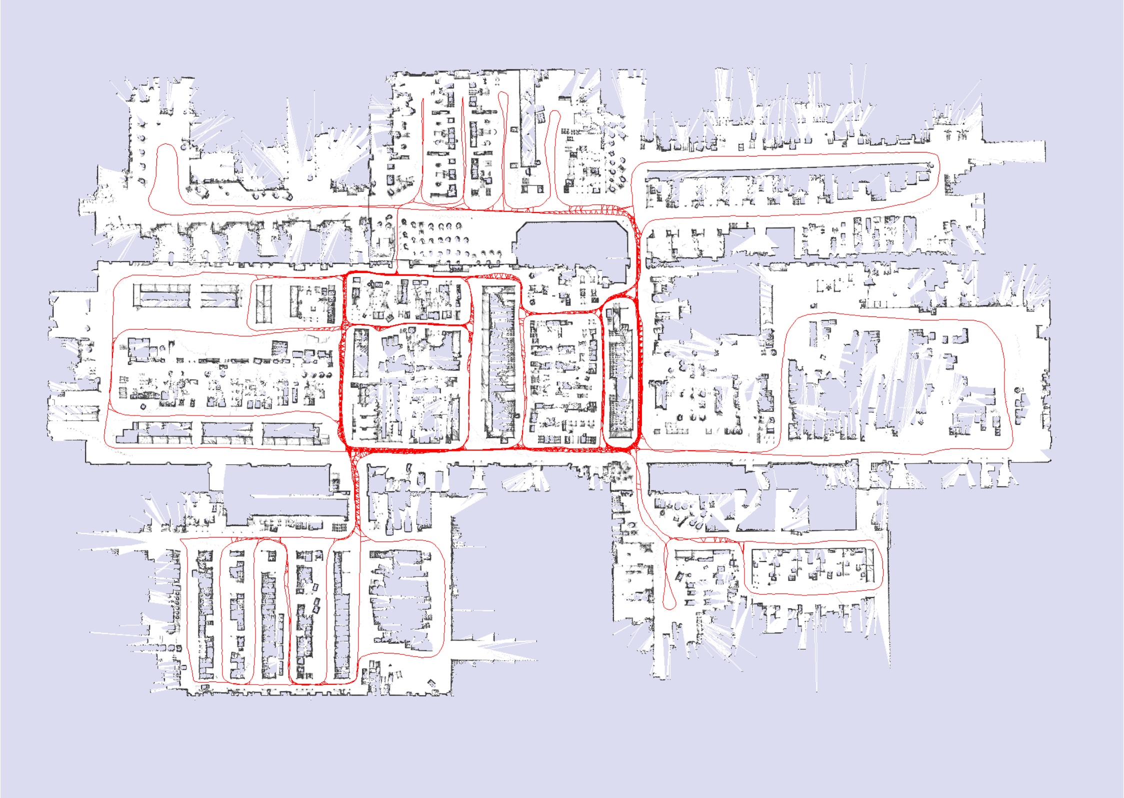

# The KUKA Production Site

| | |
|---|---|
| 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 |