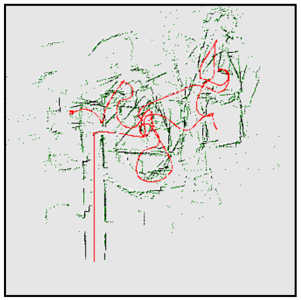
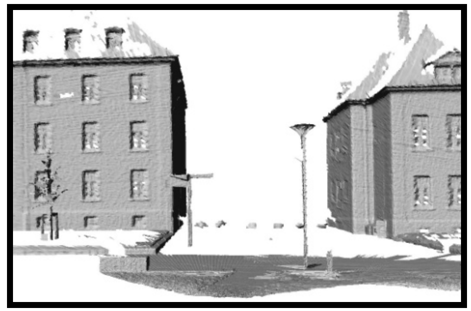
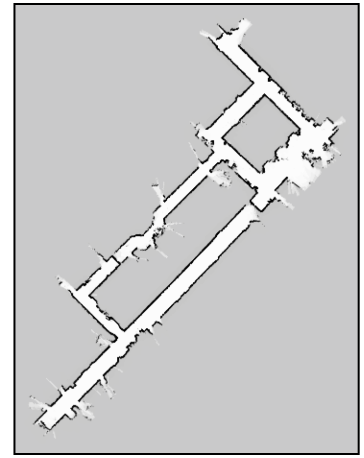
CSE-571
Probabilistic Robotics

Mapping

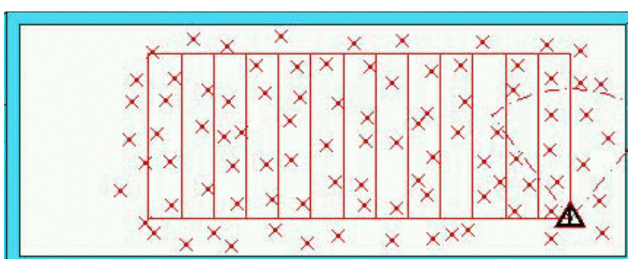
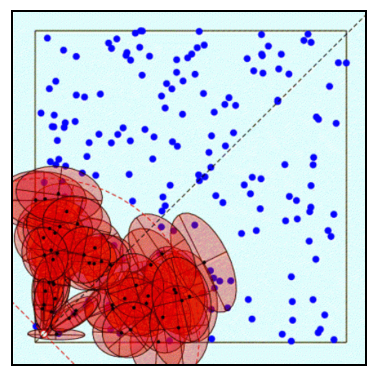
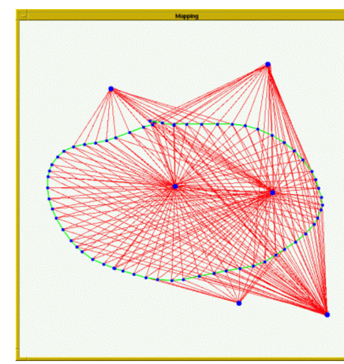
Types of SLAM-Problems

- Grid maps or scans

[Lu & Milios, 97; Gutmann, 98: Thrun 98; Burgard, 99; Konolige & Gutmann, 00; Thrun, 00; Arras, 99; Haehnel, 01;…]

- Landmark-based

[Leonard et al., 98; Castelanos et al., 99: Dissanayake et al., 2001; Montemerlo et al., 2002;…

Problems in Mapping

- Sensor interpretation
  - How do we extract relevant information from raw sensor data?
  - How do we represent and integrate this information over time?

- Robot locations have to be known
  - How can we estimate them during mapping?

Occupancy Grid Maps

- Introduced by Moravec and Elfes in 1985
- Represent environment by a grid.
- Estimate the probability that a location is occupied by an obstacle.
- Key assumptions
  - Occupancy of individual cells is independent

$$
\begin{aligned}
Bel(m_t) &= P(m_t \mid u_1, z_2 \ldots, u_{t-1}, z_t) \\
&= \prod_{x,y} Bel(m_t^{[xy]})
\end{aligned}
$$

  - Robot positions are known!

Updating Occupancy Grid Maps

- Idea: Update each individual cell using a binary Bayes filter.

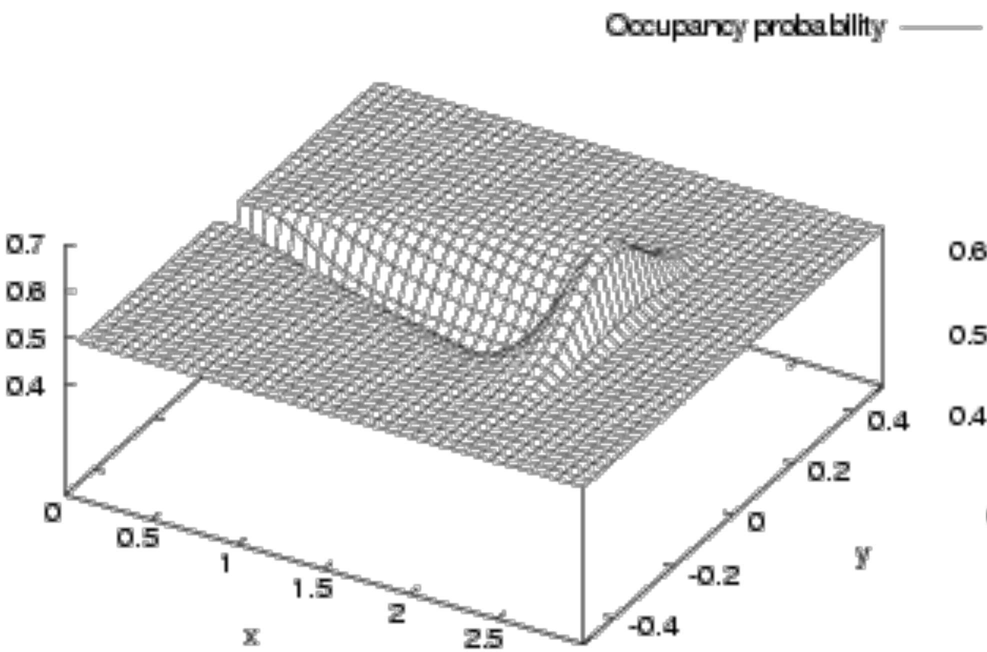
$$Bel(m_t^{[xy]}) = \eta \; p(z_t \mid m_t^{[xy]}) \sum_{m_{t-1}^{[xy]}} p(m_t^{[xy]} \mid m_{t-1}^{[xy]}, u_{t-1}) Bel(m_{t-1}^{[xy]})$$

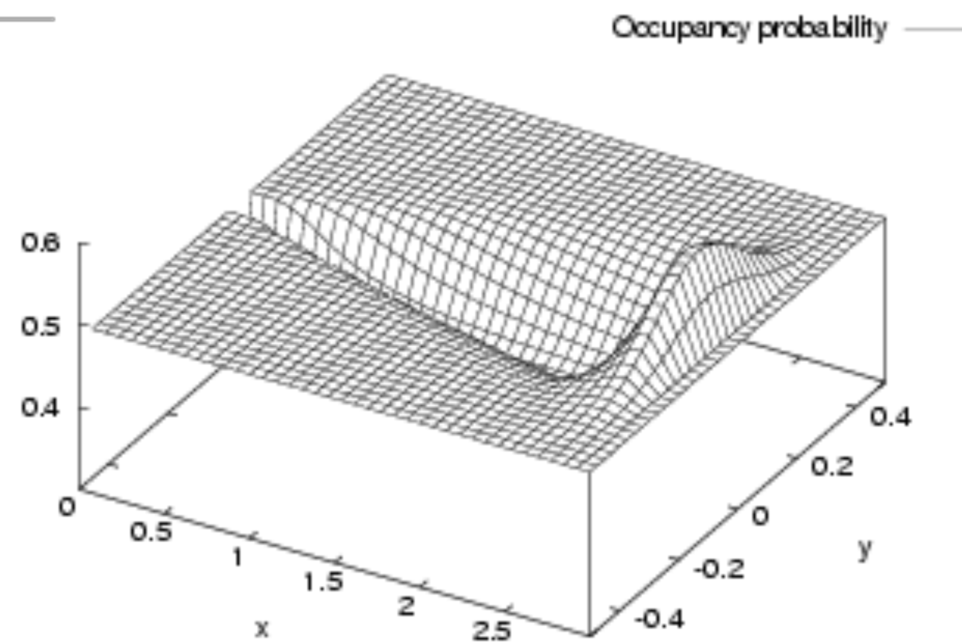
- Additional assumption: Map is static.

$$Bel(m_t^{[xy]}) = \eta \; p(z_t \mid m_t^{[xy]}) Bel(m_{t-1}^{[xy]})$$

Inverse Sensor Model for Occupancy Grid Maps

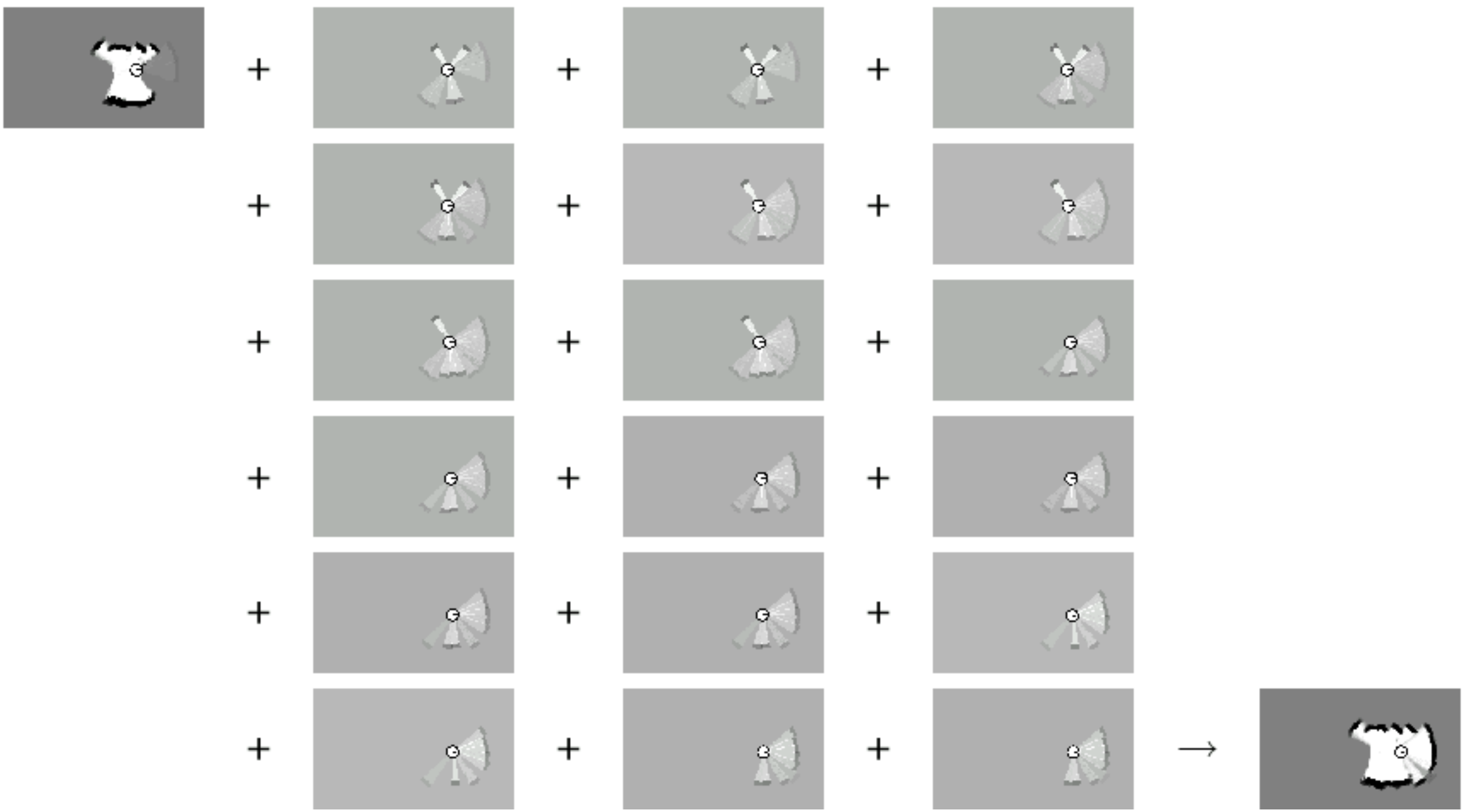
Combination of linear function and Gaussian:





$$\overline{B}\left(m_t^{[xy]}\right) = \log odds\left(m_t^{[xy]} \mid z_t, x_t\right) - \log odds\left(m_t^{[xy]}\right) + \overline{B}\left(m_{t-1}^{[xy]}\right)$$

Incremental Updating of Occupancy Grids (Example)



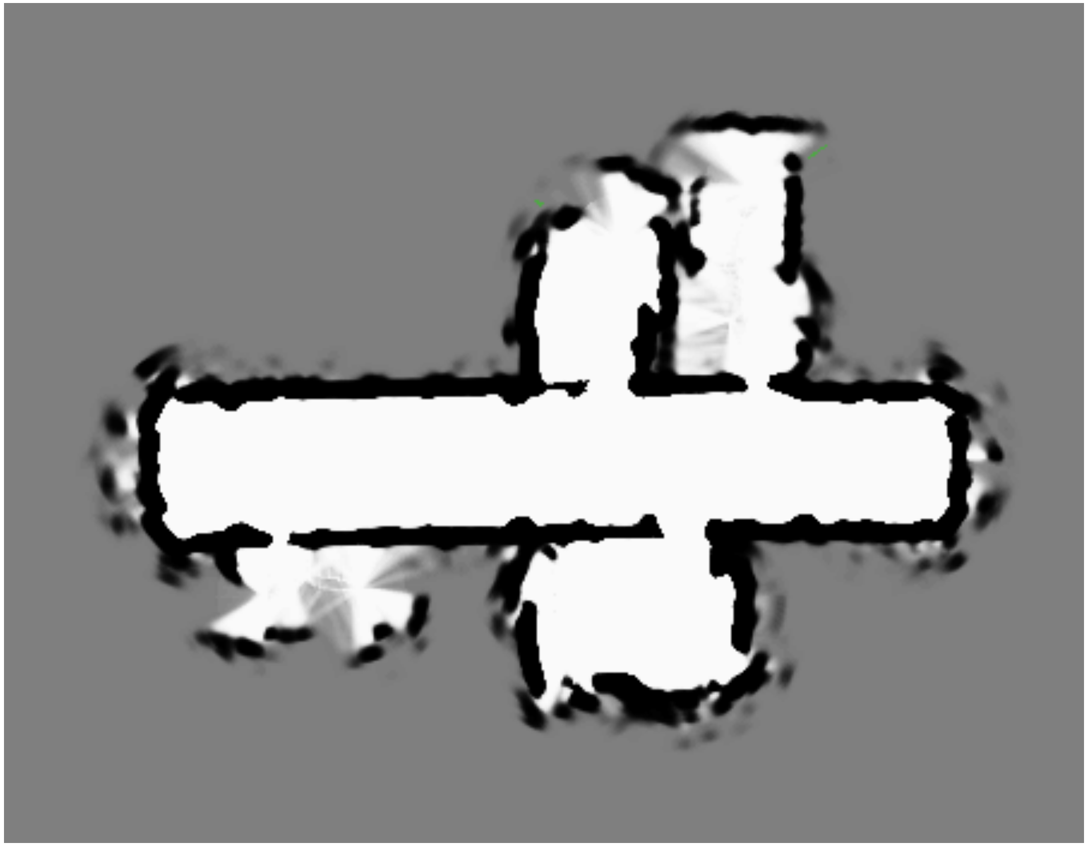
Alternative: Simple Counting

- For every cell count
  - hits(x,y): number of cases where a beam ended at <x,y>
  - misses(x,y): number of cases where a beam passed through <x,y>

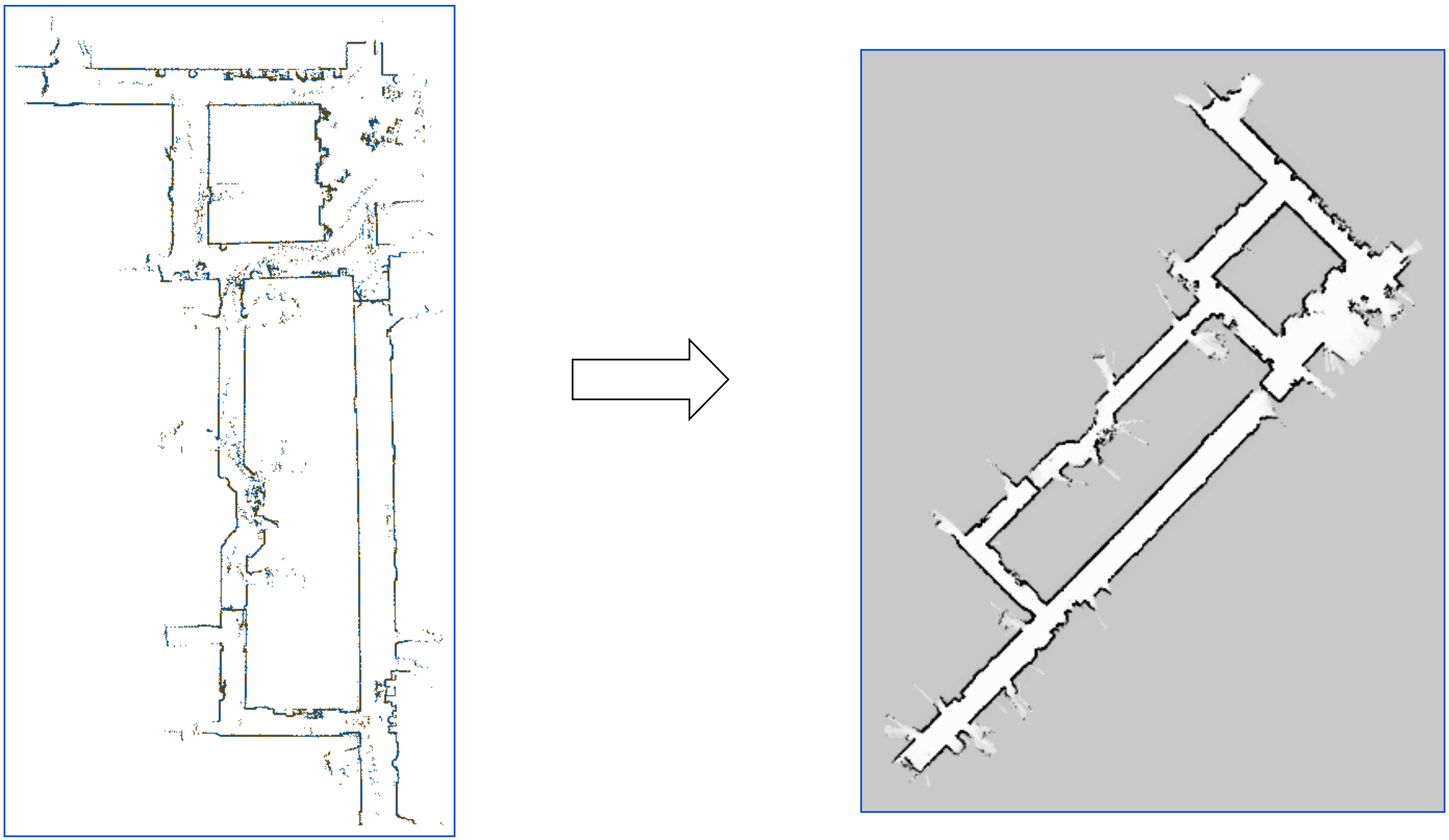
$$Bel(m^{[xy]}) = \frac{\text{hits}(x,y)}{\text{hits}(x,y) + \text{misses}(x,y)}$$

- Assumption: $P(occupied(x,y)) = P(reflects(x,y))$

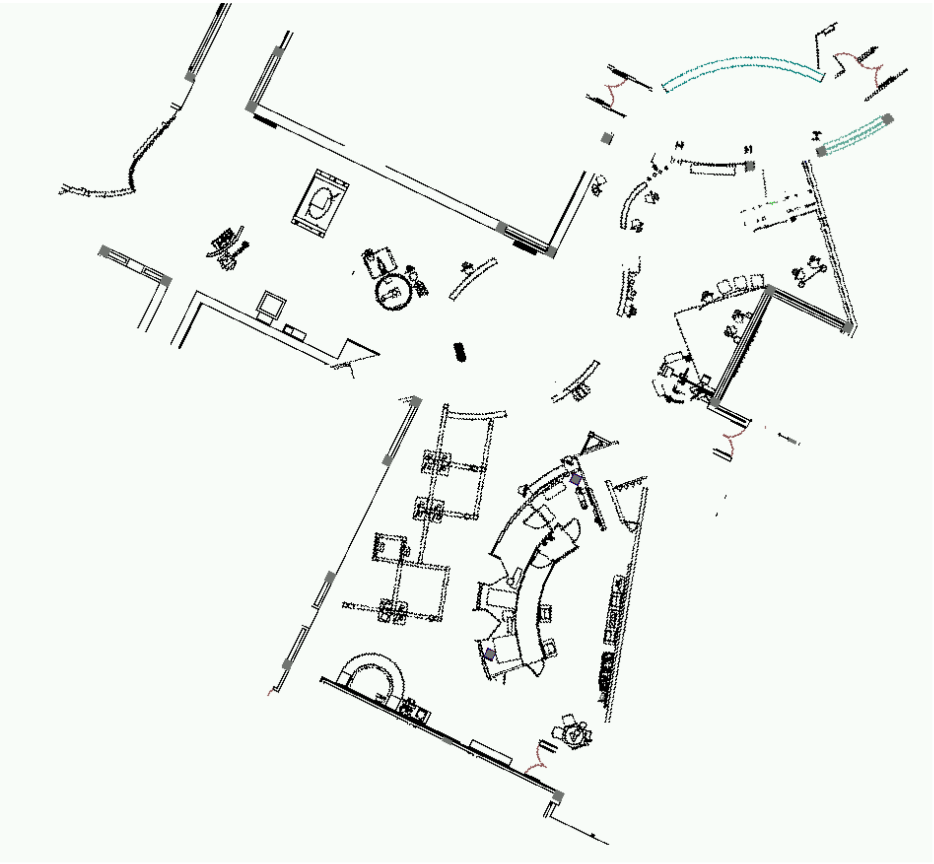
Resulting Map Obtained with Ultrasound Sensors



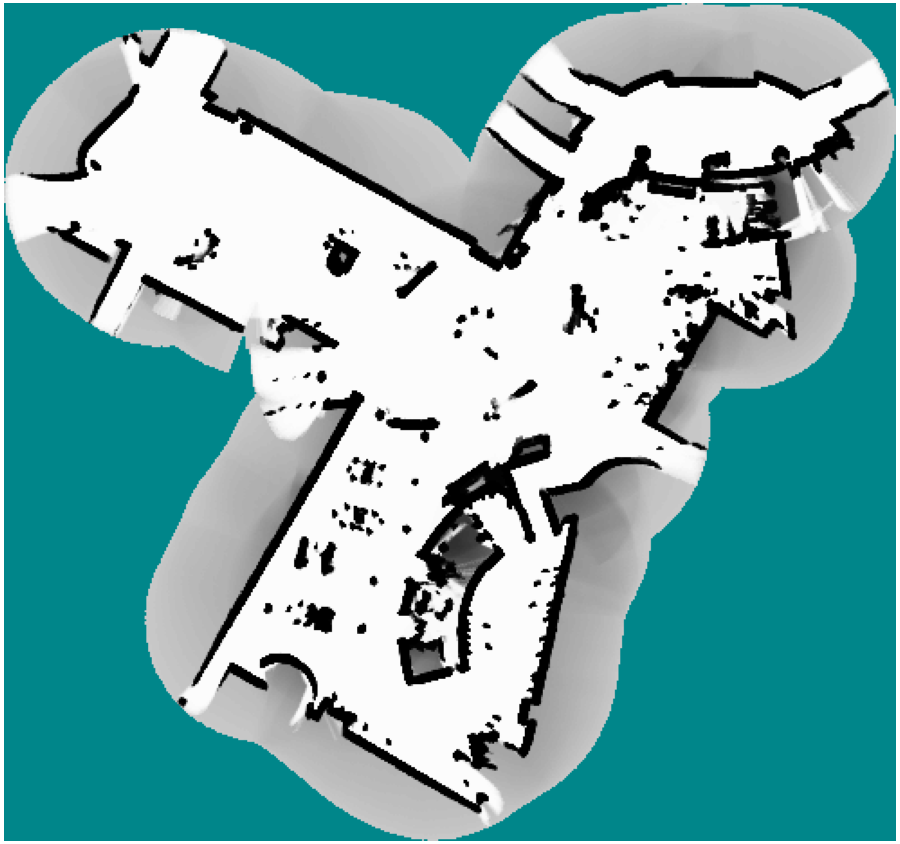
Occupancy Grids: From scans to maps



Tech Museum, San Jose



CAD map



occupancy grid map