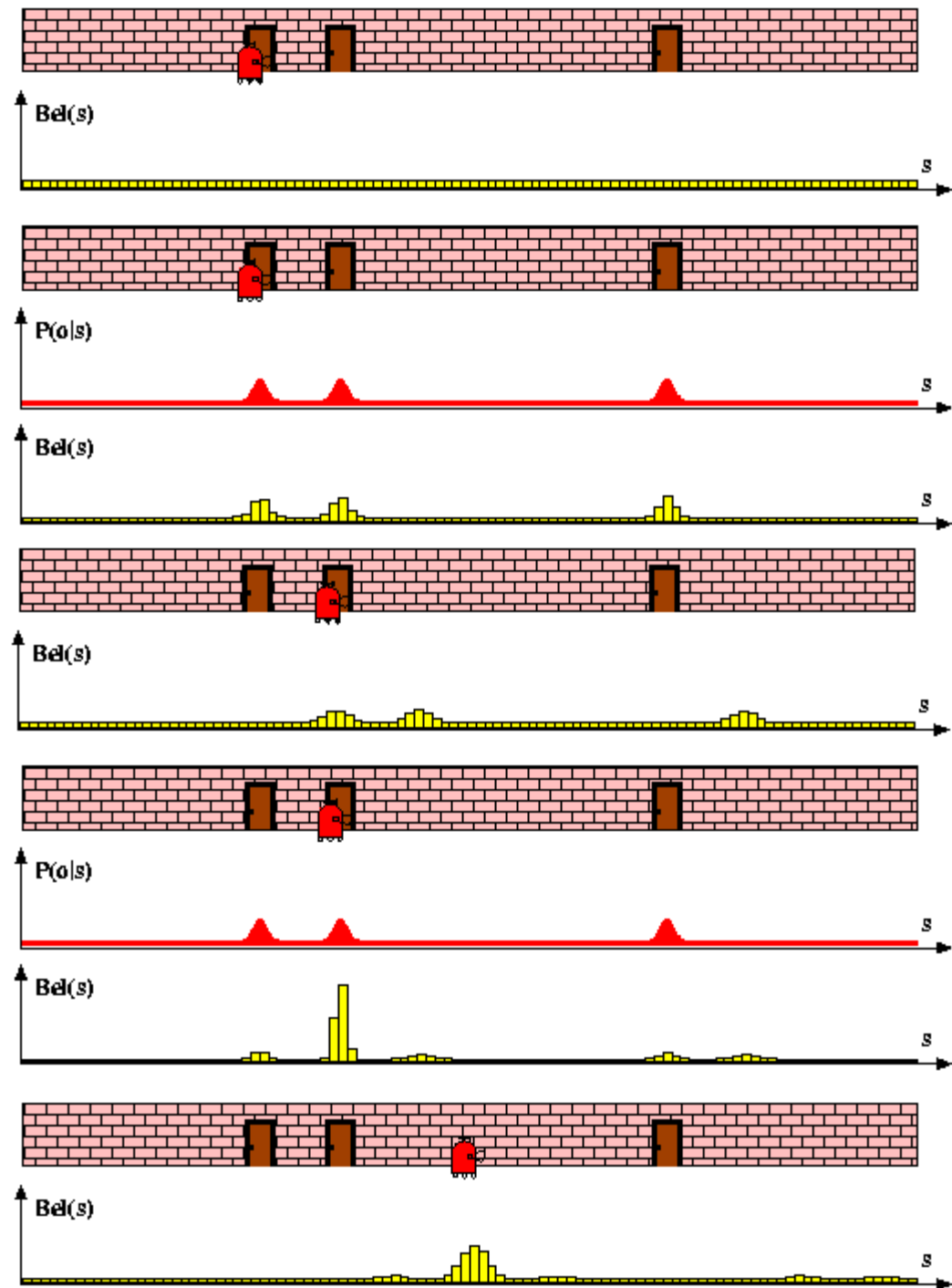# Probabilistic Robotics

Bayes Filter Implementations

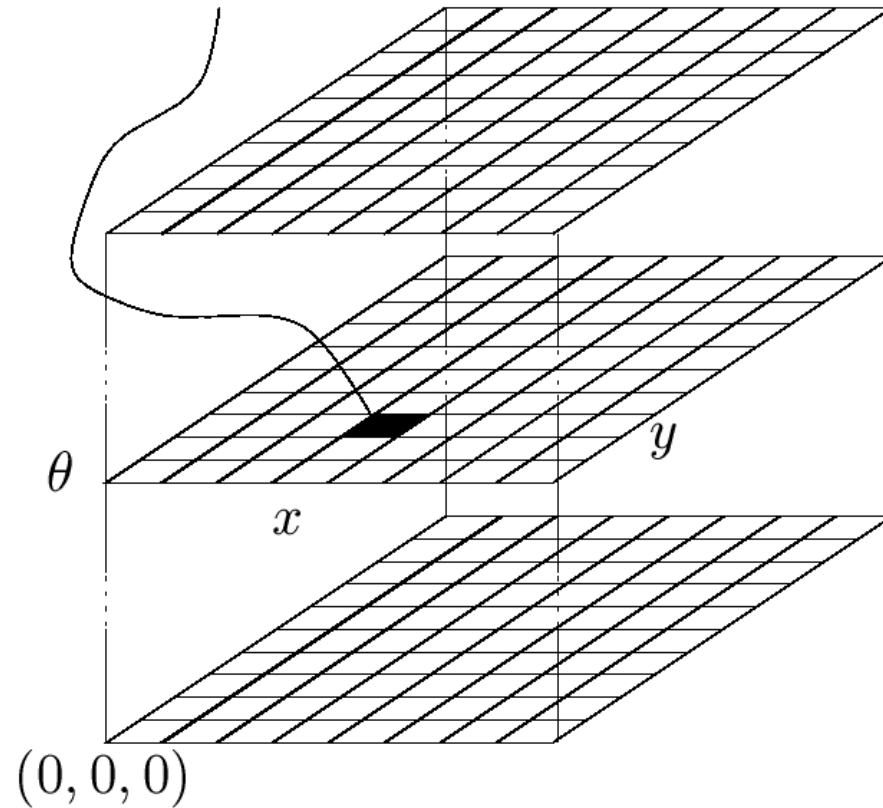Discrete filters

Piecewise Constant

Discrete Bayes Filter Algorithm

1.   Algorithm **Discrete_Bayes_filter**(*Bel(x),d*):
2. $\eta = 0$
3.   If *d* is a perceptual data item *z* then
4.   For all *x* do
5. $Bel'(x) = P(z \mid x)Bel(x)$
6. $\eta = \eta + Bel'(x)$
7.   For all *x* do
8. $Bel'(x) = \eta^{-1}Bel'(x)$

9.   Else if *d* is an action data item *u* then
10.   For all *x* do
11. $Bel'(x) = \sum_{x'} P(x \mid u, x')\, Bel(x')$
12.   Return *Bel''(x)*

Piecewise Constant Representation

$$Bel(x_t = <x, y, \theta>)$$

Implementation (1)

- To update the belief upon sensory input and to carry out the normalization one has to iterate over all cells of the grid.

- Especially when the belief is peaked (which is generally the case during position tracking), one wants to avoid updating irrelevant aspects of the state space.

- One approach is not to update entire sub-spaces of the state space.

- This, however, requires to monitor whether the robot is de-localized or not.

- To achieve this, one can consider the likelihood of the observations given the active components of the state space.

Implementation (2)

- To efficiently update the belief upon robot motions, one typically assumes a bounded Gaussian model for the motion uncertainty.
- This reduces the update cost from $O(n^2)$ to $O(n)$, where n is the number of states.
- The update can also be realized by shifting the data in the grid according to the measured motion.
- In a second step, the grid is then convolved using a separable Gaussian Kernel.
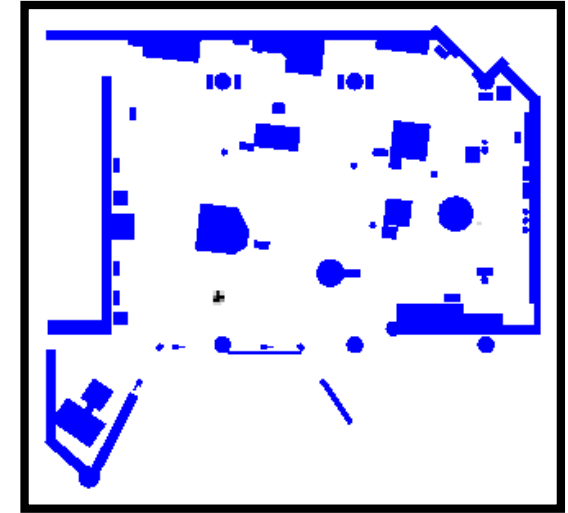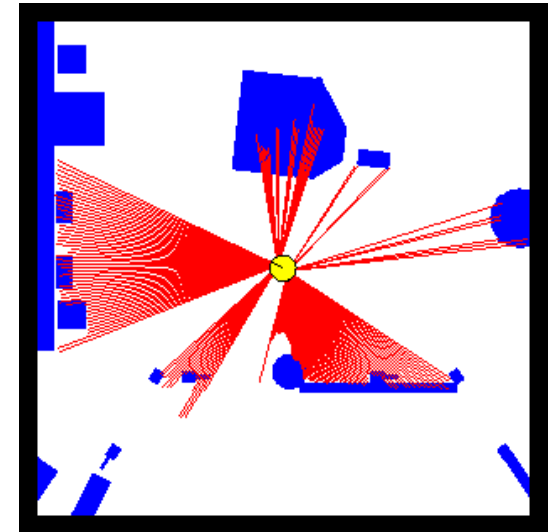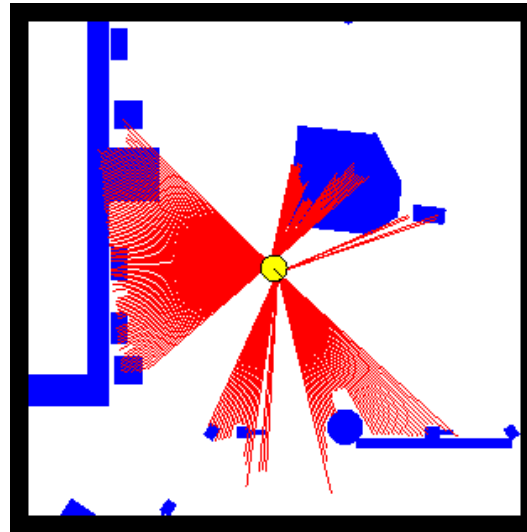- Two-dimensional example:

1/16	1/8	1/16
1/8	1/4	1/8
1/16	1/8	1/16

$\cong$

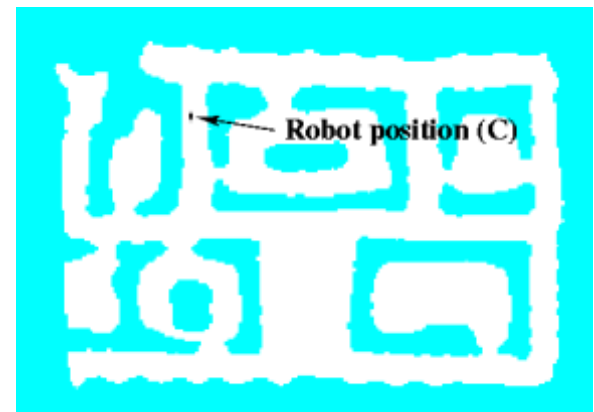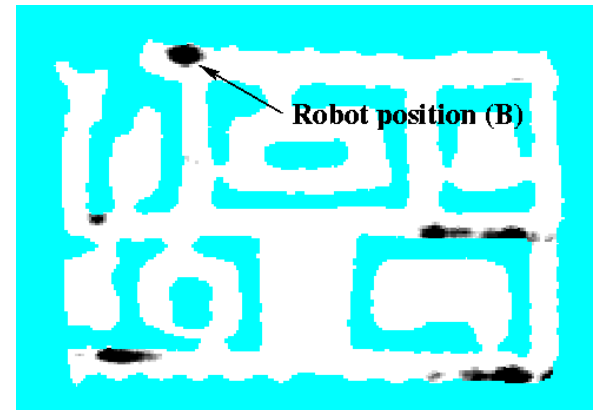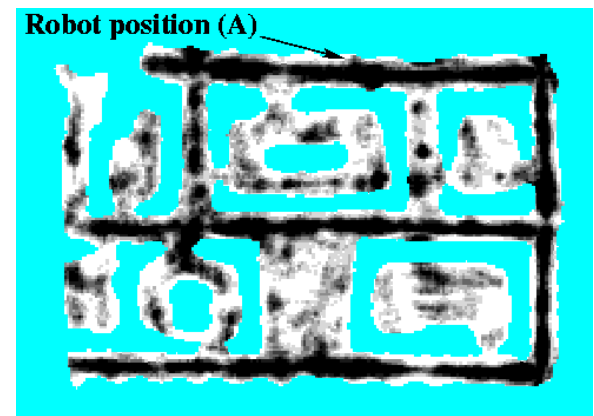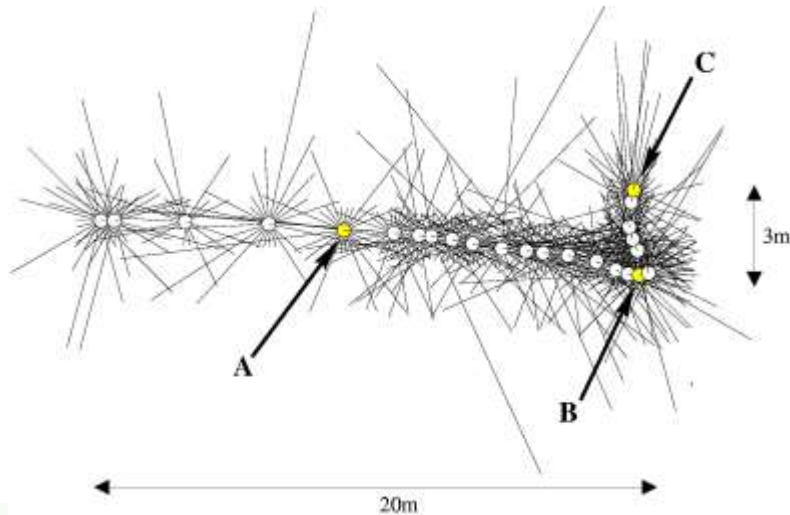| 1/4 |
|-----|
| 1/2 |
| 1/4 |

$+$

1/4	1/2	1/4

- Fewer arithmetic operations
- Easier to implement
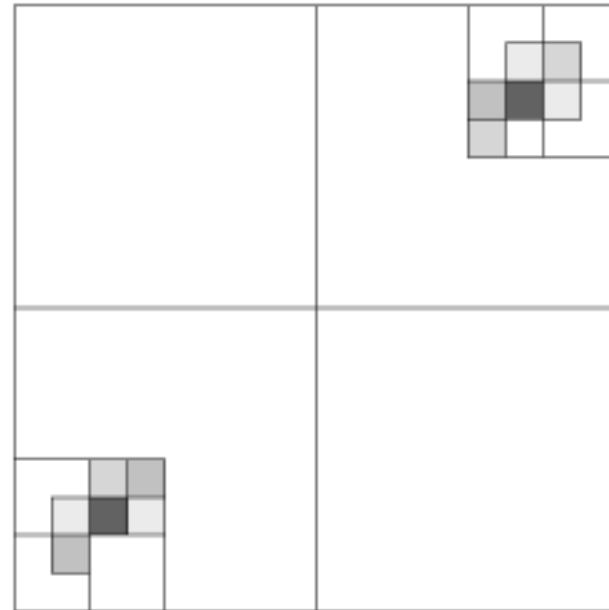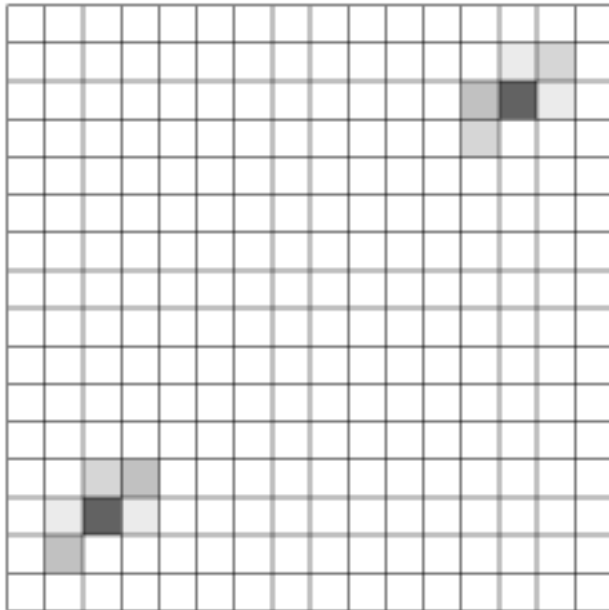
Grid-based Localization
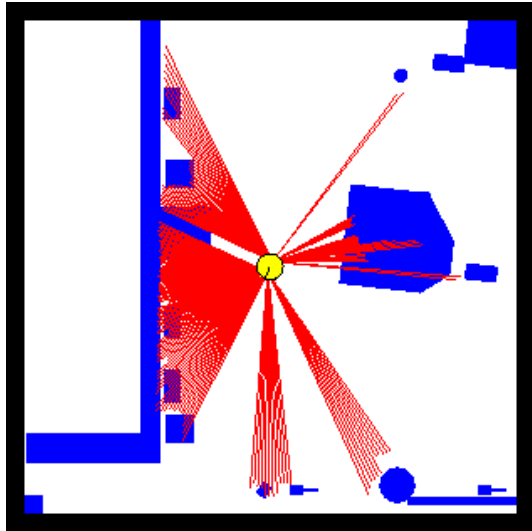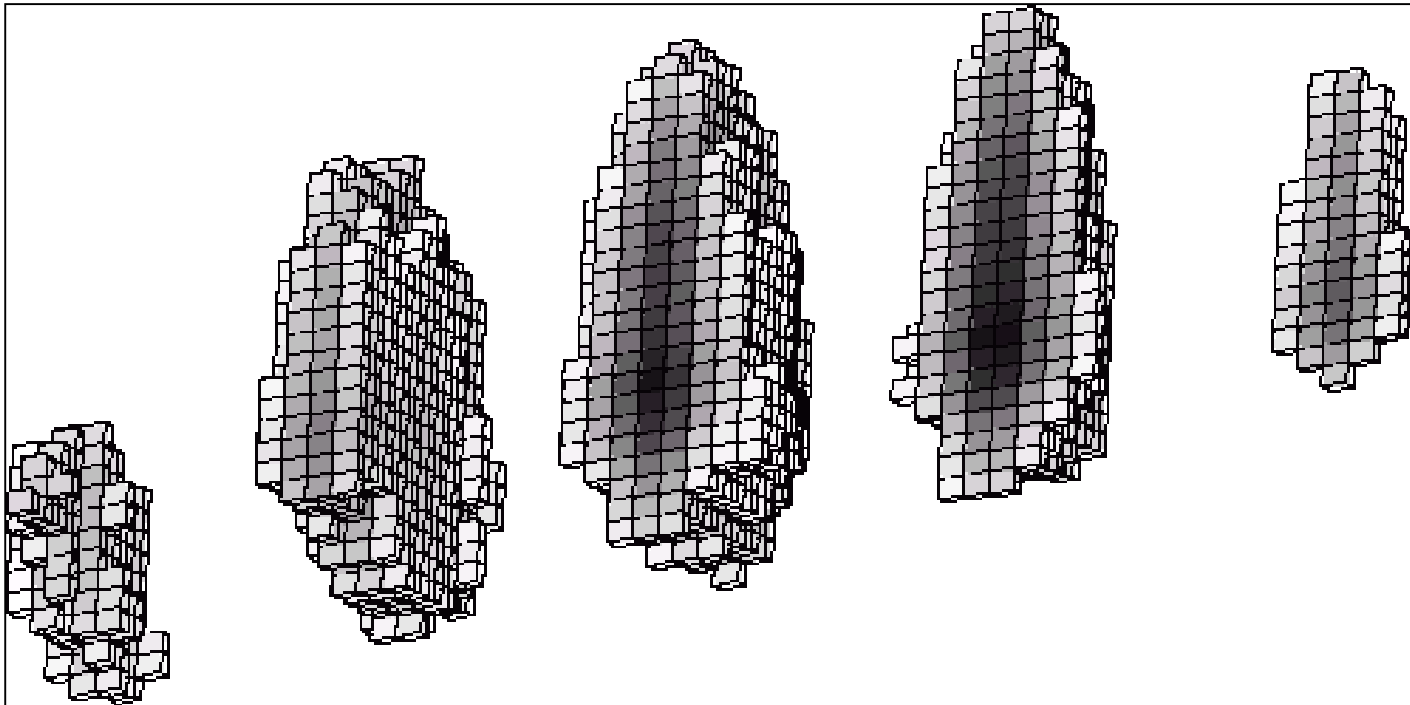
Sonars and Occupancy Grid Map

Tree-based Representation

Idea: Represent density using a variant of octrees

Tree-based Representations

- Efficient in space and time
- Multi-resolution

Xavier:
Localization in a Topological Map

[Courtesy of Reid Simmons]