

CS354

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State Estimation

- The goal is to estimate the state of the robot from a history of observations:

$$Bel(X_t) = P(X_k | Z_1, Z_2, \dots, Z_k)$$

- We make some (true-ish) simplifying assumptions:
 - Markov Assumption:

$$P(X_k | X_1, X_2, \dots, X_{k-1}) = P(X_k | X_{k-1})$$

- Assumption that the current observation only depends on the current state:

$$P(Z_t | X_1, Z_1, X_2, \dots, Z_{t-1}, X_t) = P(Z_t | X_t)$$

Probabilistic State Representations: Grid-Based

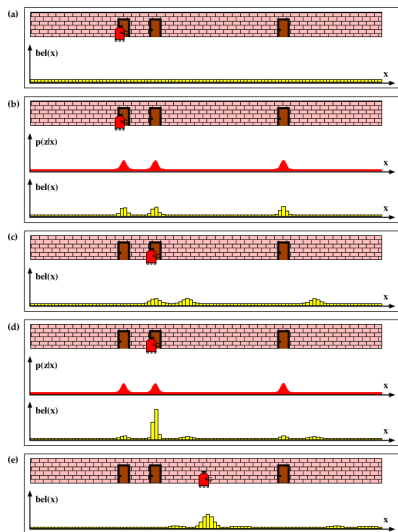


Figure 8.1 Grid localization using a fine-grained metric decomposition. Each picture depicts the position of the robot in the hallway along with its belief $bel(x_t)$, represented by a histogram over a grid.

Probabilistic Robotics. Thrun, Burgard, Fox, 2005

The Answer! Recursive State Estimation

- Two Steps:
 - **Prediction** based on system dynamics:

$$Bel^-(X_t) = \sum_{x_{t-1} \in X} P(X_t | x_{t-1}) Bel(x_{t-1})$$

- **Correction** based on sensor reading:

$$Bel(X_t) = \eta P(Z_t | X_t) Bel^-(X_t)$$

Repeat forever.

Again η is a normalizing constant chosen to make the distribution sum to 1.

Prediction Example

- The robot is now moving Right! (or trying to)
- Motion model: Robot is 80% likely to move the direction he intends to move. 20% likely to fail and not move.
- Assume we know that the robot starts in position a,
 $Bel(X_0) =$

a	b	c	d
1	0	0	0

- Or:
 $Bel(X_0 = a) = 1$
 $Bel(X_0 = b) = 0$
...

Prediction Example

- Run one step of prediction:

$$\begin{aligned} \text{Bel}^-(X_1 = a) &= \sum_{x_0 \in X} P(x_1 = a | x_0) \text{Bel}(x_0) \\ &= P(X_1 = a | X_0 = a) \text{Bel}(X_0 = a) + \\ &\quad P(X_1 = a | X_0 = b) \text{Bel}(X_0 = b) + \\ &\quad P(X_1 = a | X_0 = c) \text{Bel}(X_0 = c) + \\ &\quad P(X_1 = a | X_0 = d) \text{Bel}(X_0 = d) \\ &= .2 \times 1 + 0 \times 0 + 0 \times 0 + .8 \times 0 \\ &= .2 \end{aligned}$$

Prediction Example

- Similarly

$$Bel^-(X_1 = b) = .8 \times 1 + .2 \times 0 + 0 \times 0 + 0 \times 0 = .8$$

$$Bel^-(X_1 = c) = 0$$

$$Bel^-(X_1 = d) = 0$$

- Unsurprisingly, $Bel^-(X_1) =$

a	b	c	d
.2	.8	0	0

Estimation

Now that we have a prediction, we can update it based on the latest sensor reading:

$$Bel(X_t) = \eta P(Z_t | X_t) Bel^-(X_t)$$

This is *exactly* what we did when we talked about using Bayes rule to update a prior state estimate based on a sensor reading.

The process is then repeated indefinitely.