$$Bel(\mathbf{x}_t) = p(\mathbf{x}_t|\mathbf{y}_{1\ldots t})$$

- $p(\mathbf{y}_t|\mathbf{x}_t)$ - measurements model
- $p(\mathbf{x}_t|\mathbf{x}_{t-1})$ - system model

prognosis:

$$Bel^{-}(\mathbf{x}_t) = \int p(\mathbf{x}_t|\mathbf{x}_{t-1}) \cdot Bel(\mathbf{x}_{t-1}) d\mathbf{x}_{t-1}$$

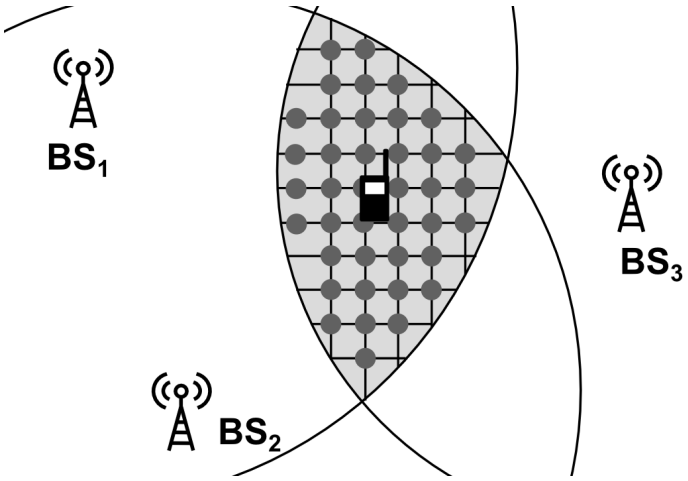
update:

$$Bel(\mathbf{x}_t) = \frac{p(\mathbf{y}_t|\mathbf{x}_t) \cdot Bel^{-}(\mathbf{x}_t)}{p(\mathbf{y}_t)}$$

implementations:

- Discrete Bayes filter
- Kalman filter
- Particle filter

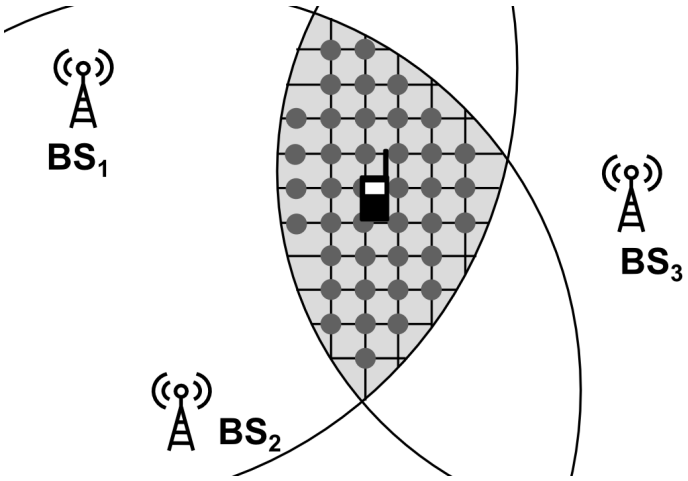
Discrete Bayes filter: algorithm



- Divide location area on points (discrete grid)
- Estimate points probabilities: $P(\mathbf{x}_{t,i}|\mathbf{y}_{1\ldots t}) = \frac{P(\mathbf{y}_t|\mathbf{x}_{t,i})P(\mathbf{x}_{t,i}|\mathbf{y}_{1\ldots t-1})}{P(\mathbf{y}_t)}$

- $P(\mathbf{y}_t|\mathbf{x}_{t,i})$ – likelihood
- $P(\mathbf{x}_{t,i}|\mathbf{y}_{1\ldots t-1}) = \sum_{j=1}^{m} P(\mathbf{x}_{t,i}|\mathbf{x}_{t-1,j}) \cdot P(\mathbf{x}_{t-1,j}|\mathbf{y}_{1\ldots t-1})$ – prior probabilities
- $P(\mathbf{x}_{t,i}|\mathbf{x}_{t-1,j})$ – system model
- $P(\mathbf{x}_{t-1,j}|\mathbf{y}_{1\ldots t-1})$ – previous estimations

Discrete Bayes filter: algorithm



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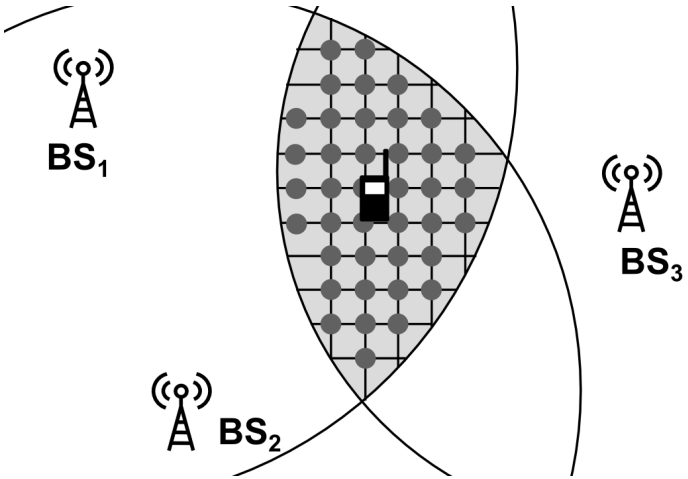
Discrete Bayes filter: algorithm



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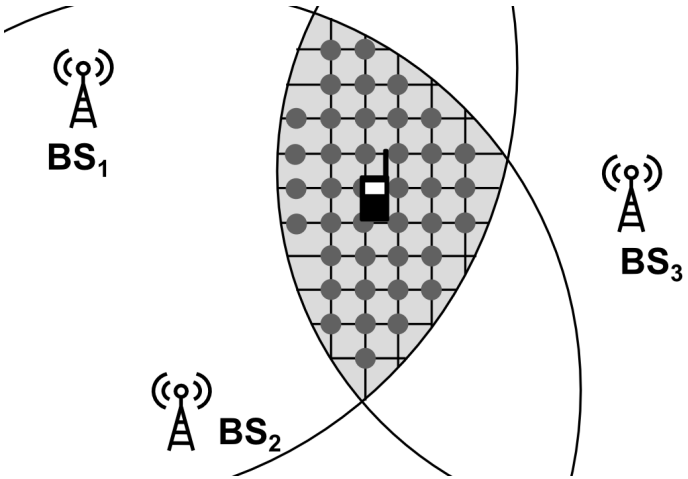
Discrete Bayes filter: algorithm



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- $P(\mathbf{y}_t|\mathbf{x}_{t,i})$ – likelihood
- $P(\mathbf{x}_{t,i}|\mathbf{y}_{1\ldots t-1}) = \sum_{j=1}^{m} \underline{P(\mathbf{x}_{t,i}|\mathbf{x}_{t-1,j})} \cdot P(\mathbf{x}_{t-1,j}|\mathbf{y}_{1\ldots t-1})$ – prior probabilities
- $\underline{P(\mathbf{x}_{t,i}|\mathbf{x}_{t-1,j})}$ – system model
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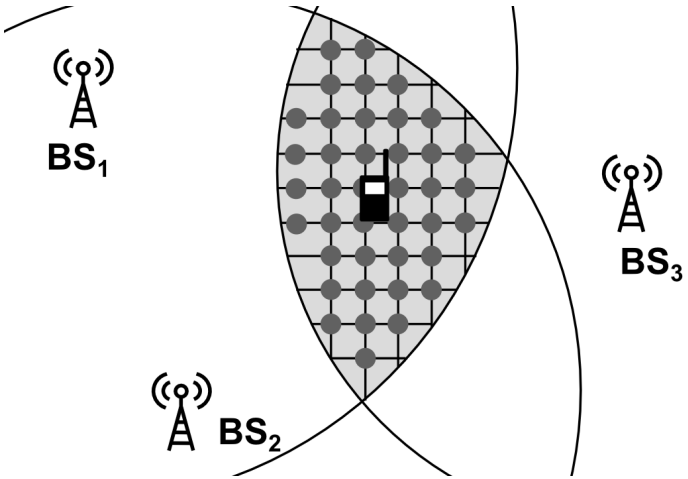
Discrete Bayes filter: algorithm



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Discrete Bayes filter: algorithm

1. initialization
2. prognosis
3. update
4. location estimation
   - building map
   - distance measurements
   - RSS map

Discrete Bayes filter: algorithm

1. initialization
2. prognosis
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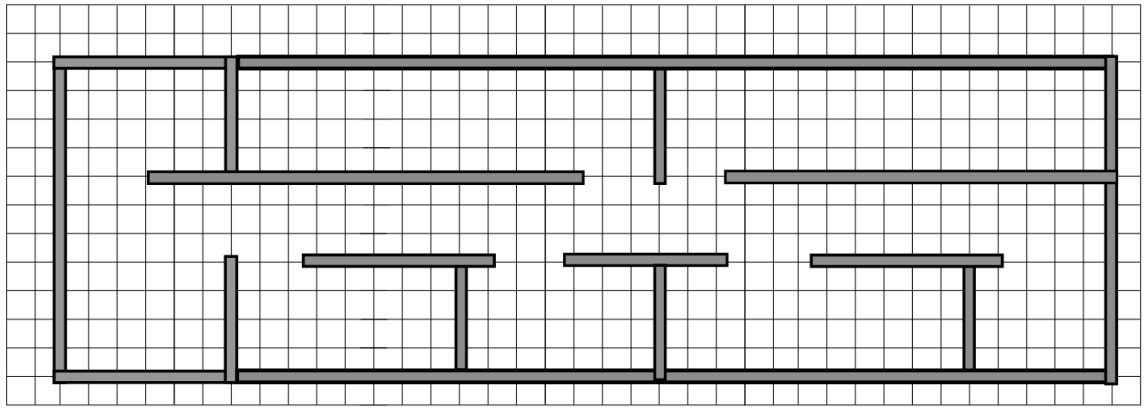

Discrete Bayes filter: algorithm

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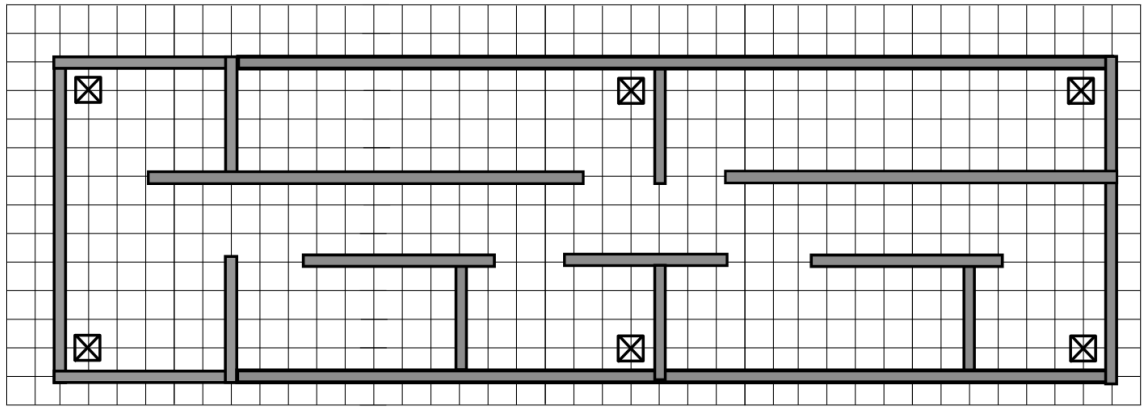

Discrete Bayes filter: algorithm

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   - building map
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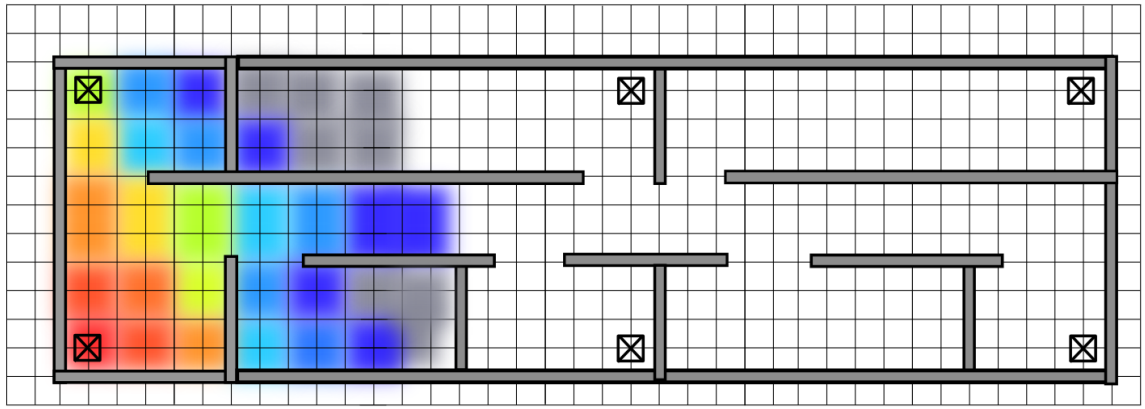

Discrete Bayes filter: algorithm

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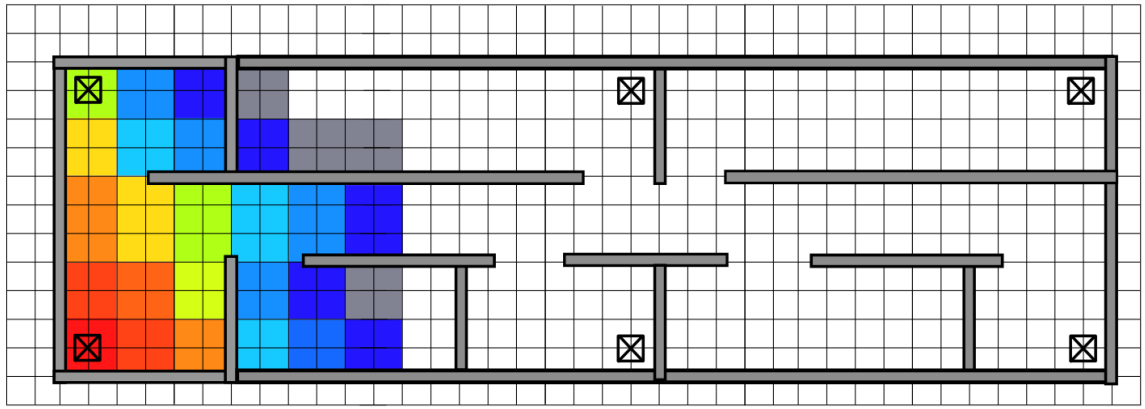

Discrete Bayes filter: algorithm

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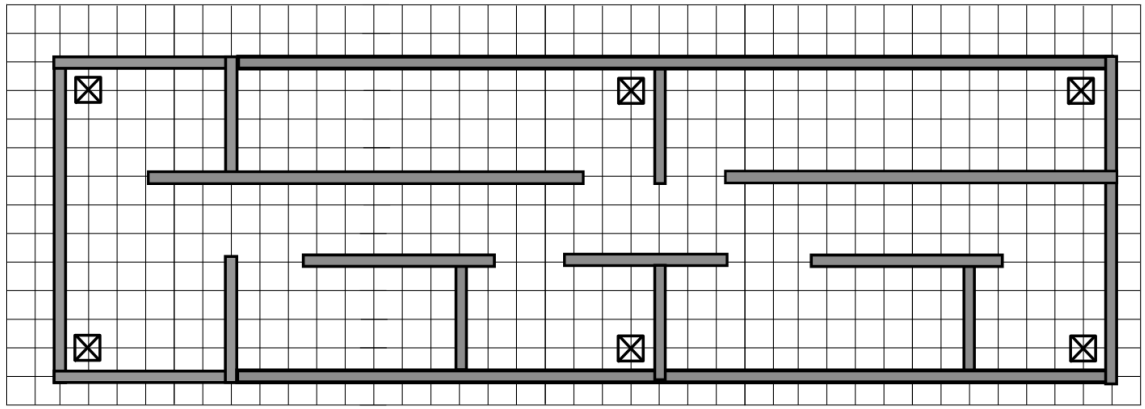
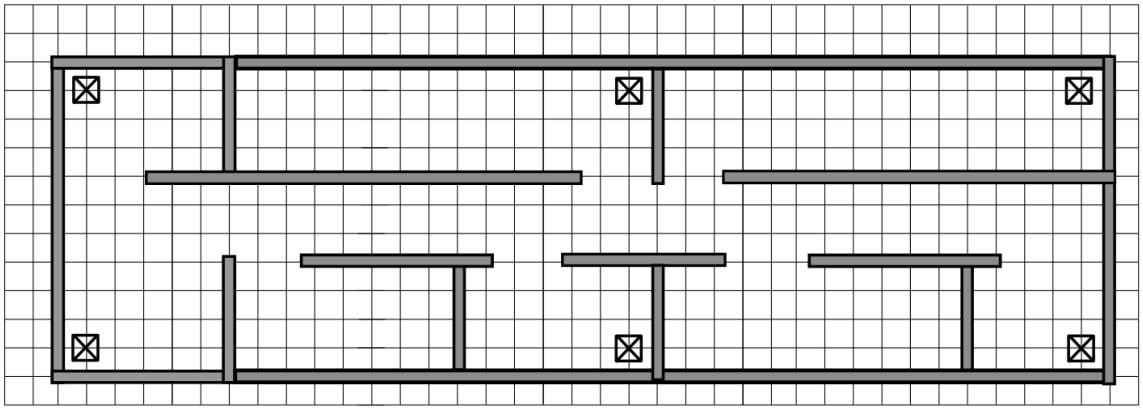


Discrete Bayes filter: algorithm

$t = 0$

1. initialization
2. prognosis
3. update
4. location estimation
   1. Divide location area with discrete grid
   2. Calculate probabilities $P(\mathbf{y}_t|\mathbf{x}_{t,i})$



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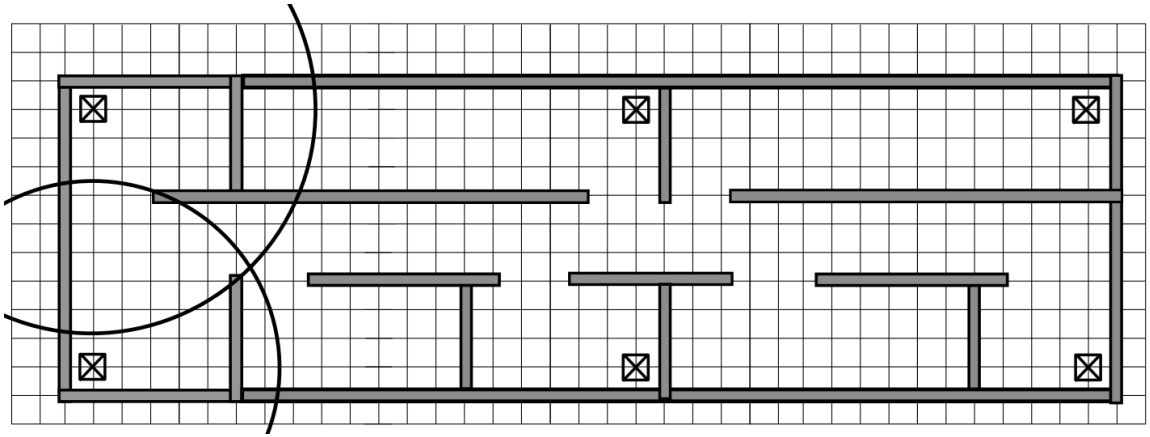

Discrete Bayes filter: algorithm

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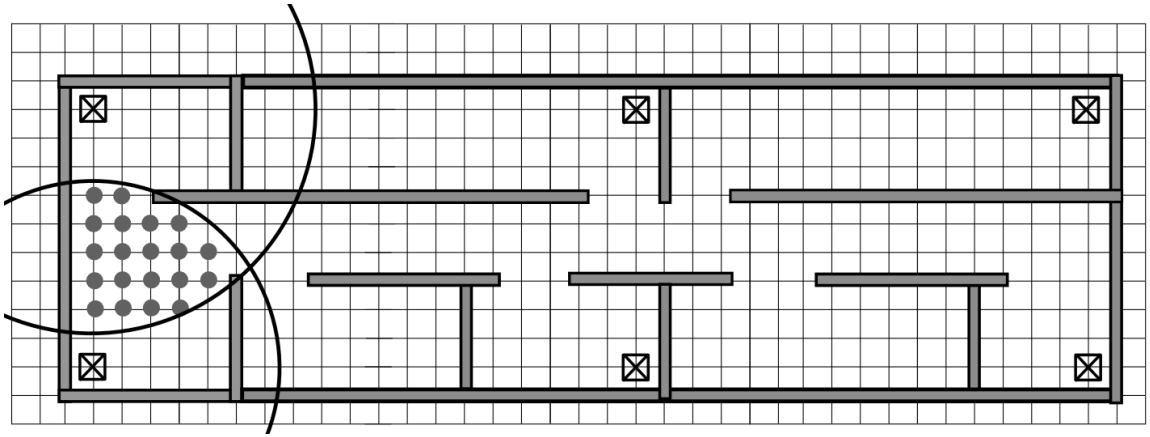

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Discrete Bayes filter: algorithm

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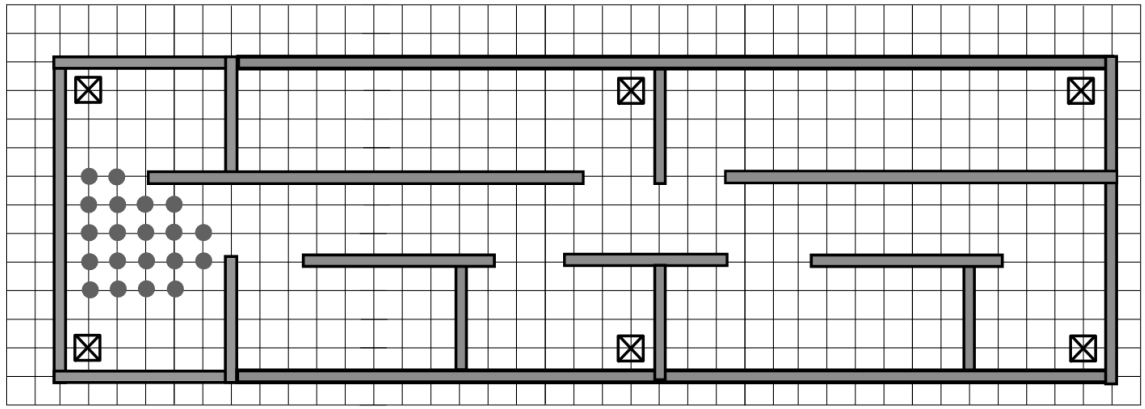

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Discrete Bayes filter: algorithm

$t = 0$

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2. prognosis
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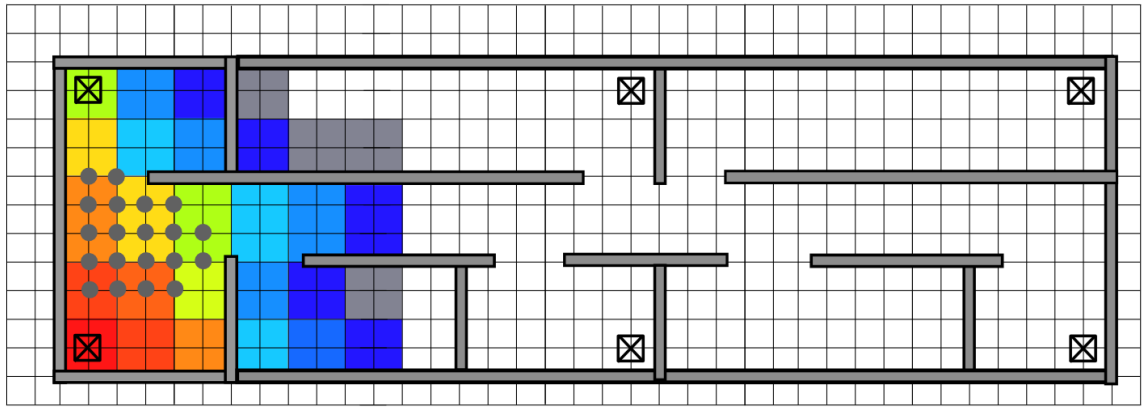

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RSS map:

$$\mathbf{s}^{offline}(c) = \{< s_{BS_1} >, < s_{BS_2} >, \ldots, < s_{BS_n} >\}$$

$$P(s_{BS_j}|c) = \left(\frac{1}{\sqrt{2\pi\sigma^2}}\right) \exp \frac{-(s_{BS_j} - < s_{BS_j} >)^2}{2\sigma^2}$$

Discrete Bayes filter: algorithm

$t = 0$

1. initialization
2. prognosis
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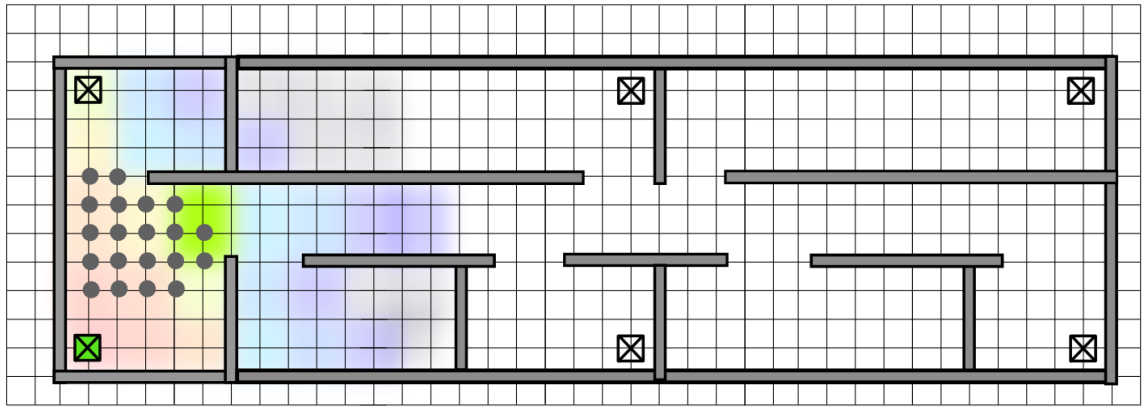
4. location estimation



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Discrete Bayes filter: algorithm

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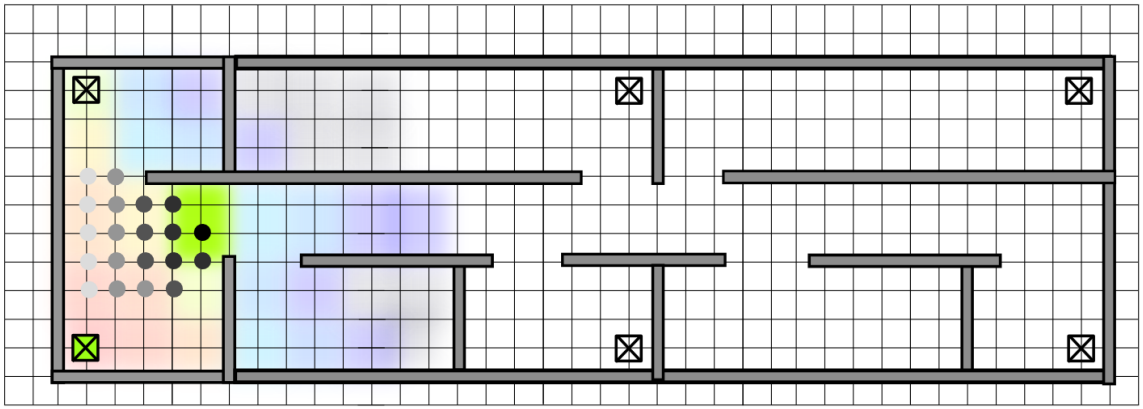
4. location estimation



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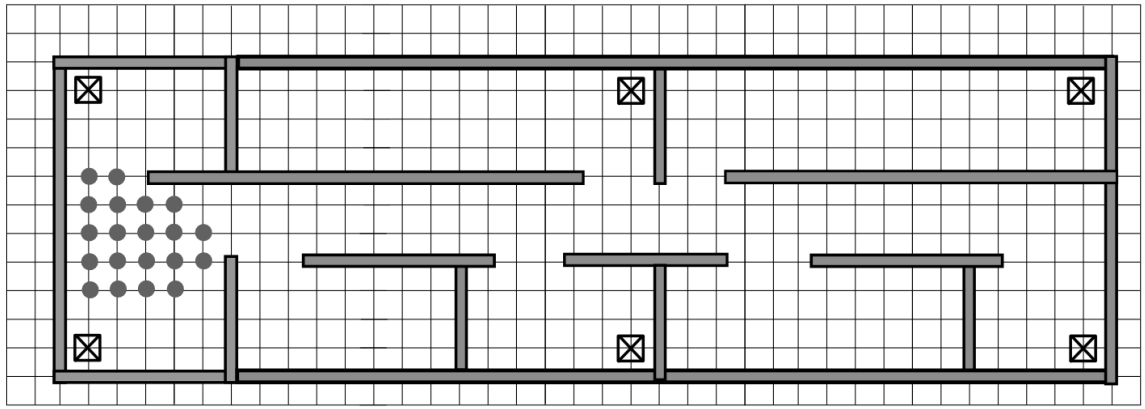
Discrete Bayes filter: algorithm

$t = 1$

1. initialization
2. prognosis
3. update
4. location estimation
    1. Expand location area
    2. Take into account building map



Discrete Bayes filter: algorithm

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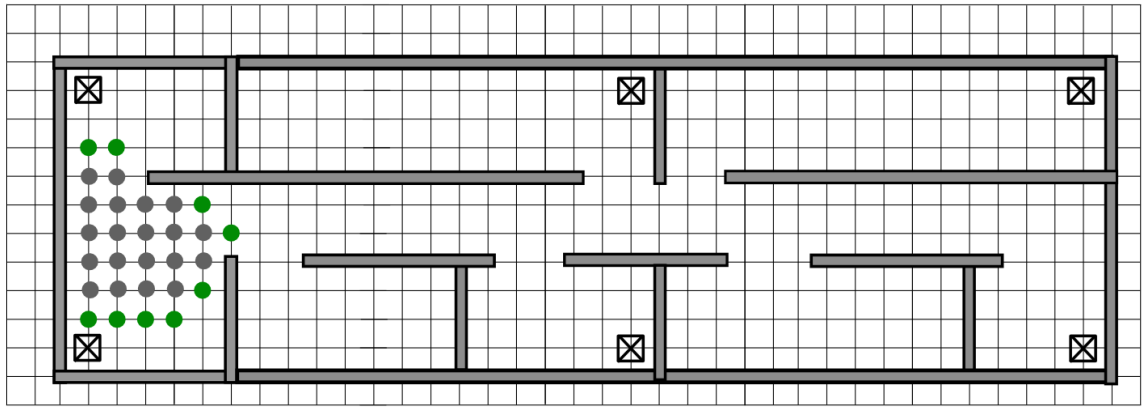

Discrete Bayes filter: algorithm

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    1. Expand location area
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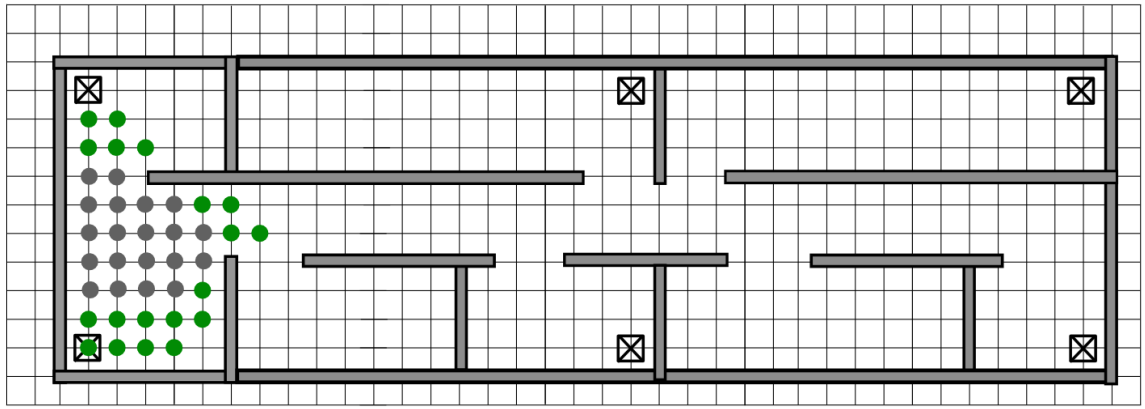

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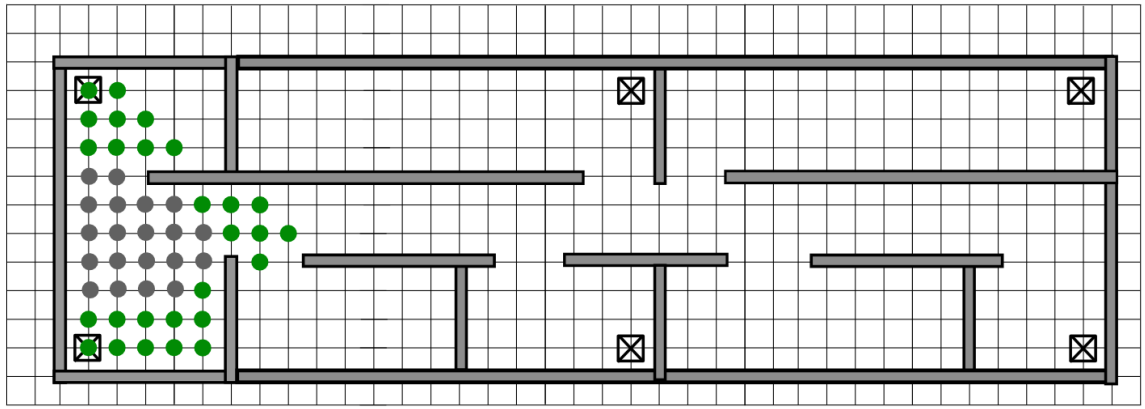

Discrete Bayes filter: algorithm

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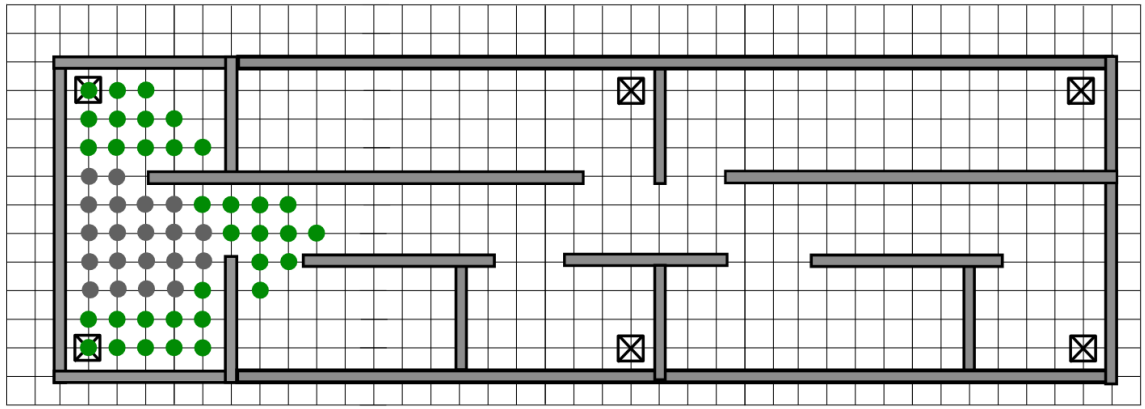
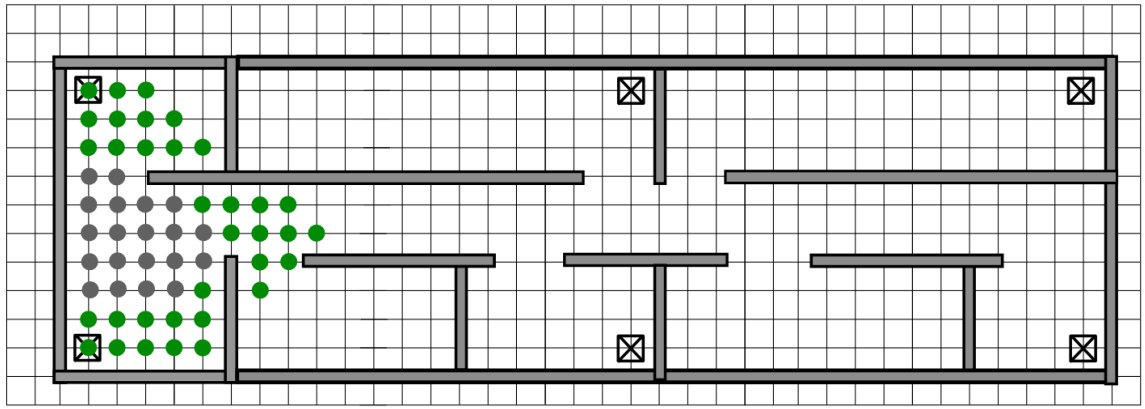


Discrete Bayes filter: algorithm

$t = 1$

1. initialization
2. prognosis
3. update
4. location estimation
   1. Select points inside circles
   2. Estimate probabilities $P(\mathbf{y}_t|\mathbf{x}_{t,i})$



Discrete Bayes filter: algorithm

$t = 1$

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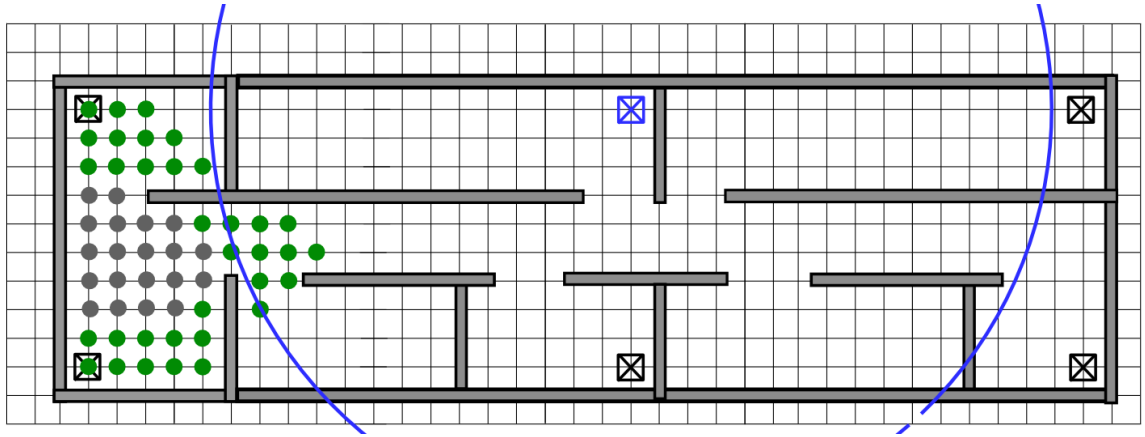
3. update
4. location estimation



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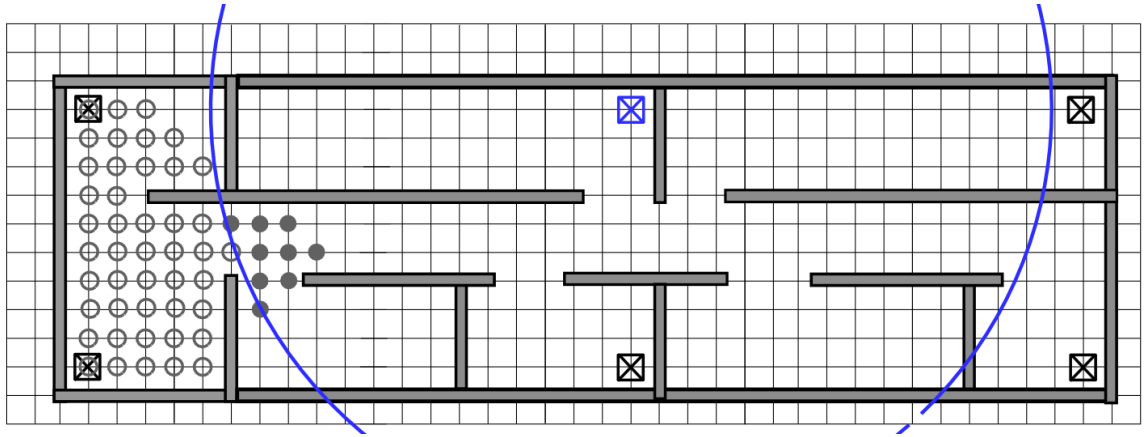

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Discrete Bayes filter: algorithm

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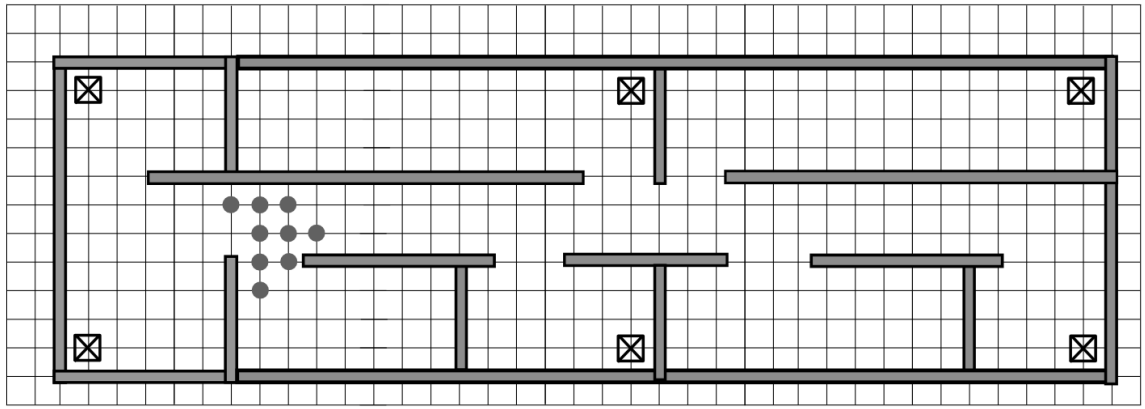

Discrete Bayes filter: algorithm

$t = 1$

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2. prognosis
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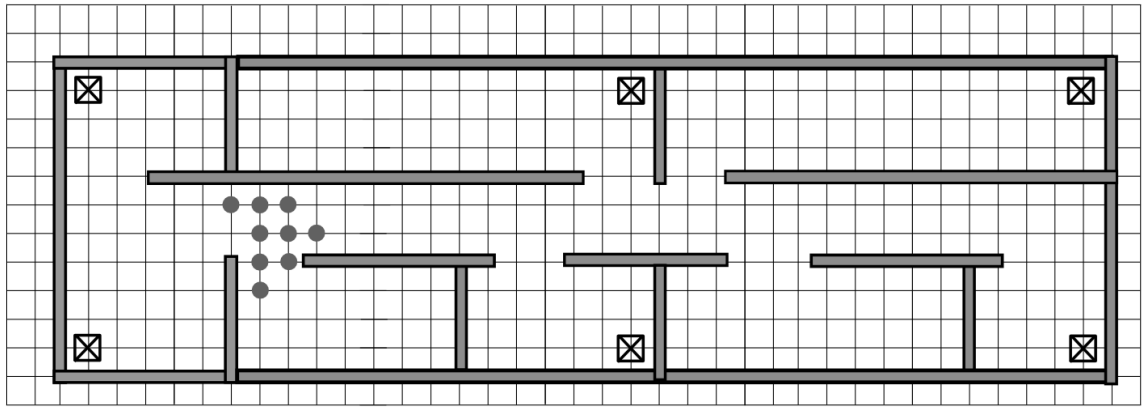

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Discrete Bayes filter: algorithm

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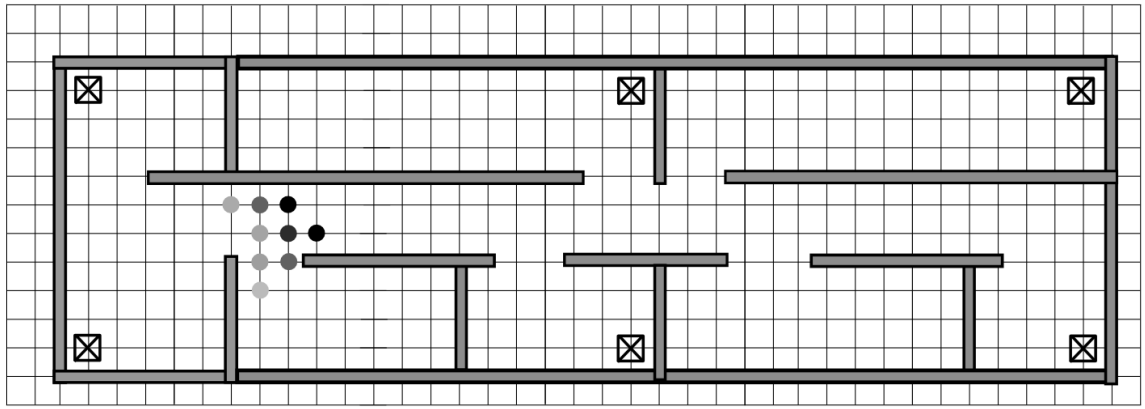

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Discrete Bayes filter: algorithm

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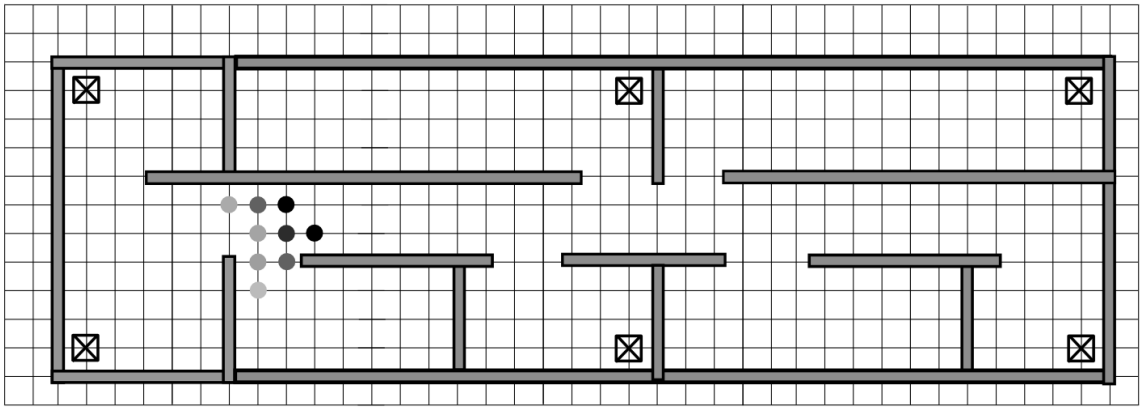
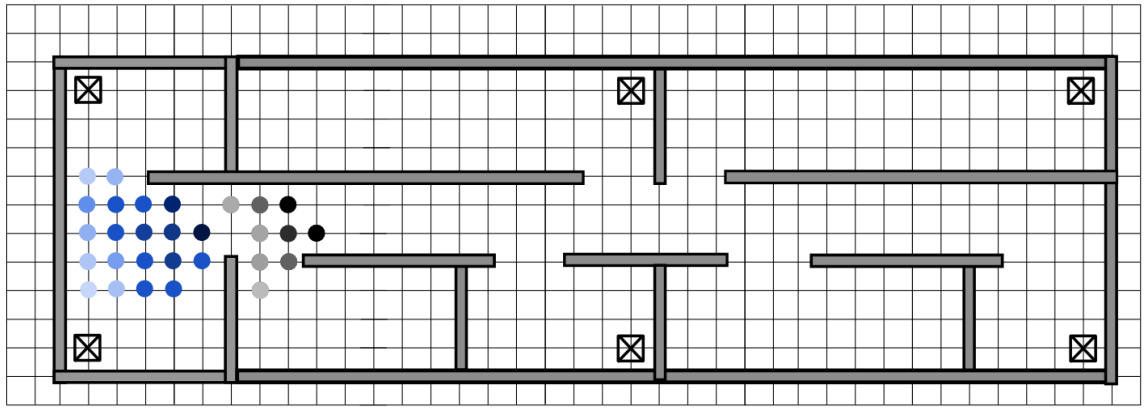


$$\hat{x}_t = \sum_{i=1}^{N} P_{t,i} \cdot x_{t,i}$$

$$\hat{y}_t = \sum_{i=1}^{N} P_{t,i} \cdot y_{t,i}$$

Discrete Bayes filter: algorithm

$t = 1$



1. initialization
2. prognosis
3. update
4. location estimation

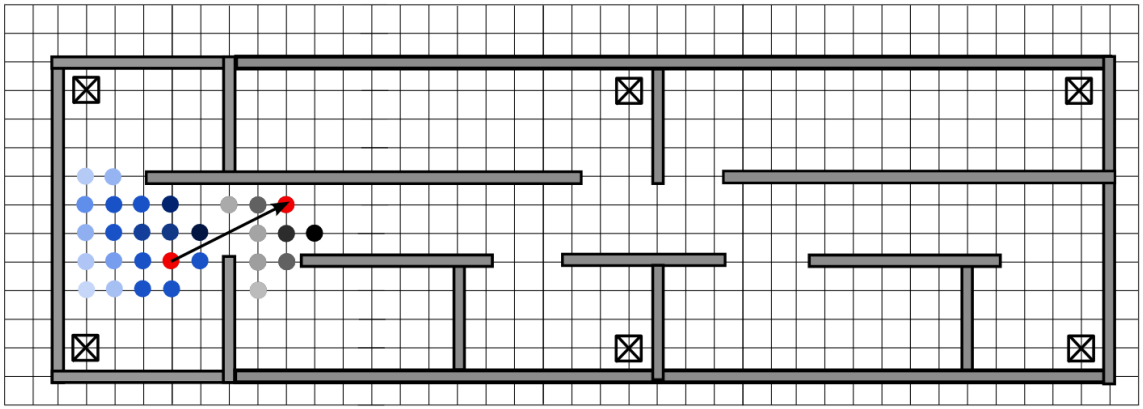
Draw velocity distribution:

- define vector $\{v_{i,j}, P = P_i \cdot P_j\}$ for each pare $x_{i,t-1}$ and $x_{j,t}$
- draw distribution for vector components (v_r, v_a):

Discrete Bayes filter: algorithm

$t = 1$

1. initialization
2. prognosis
3. update
4. location estimation



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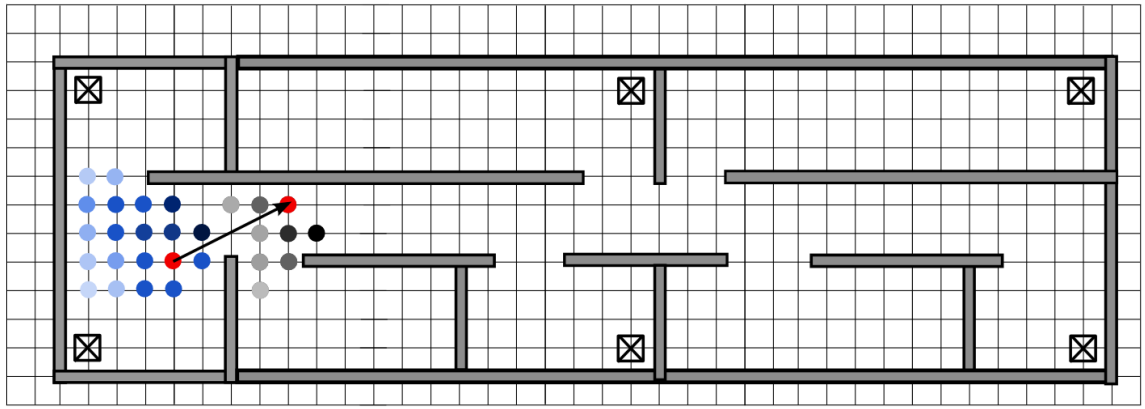
Discrete Bayes filter: algorithm

$t = 2$

1. initialization
2. prognosis
3. update
4. location estimation



Draw velocity distribution:

- define vector $\{v_{i,j}, P = P_i \cdot P_j\}$ for each pare $x_{i,t-1}$ and $x_{j,t}$
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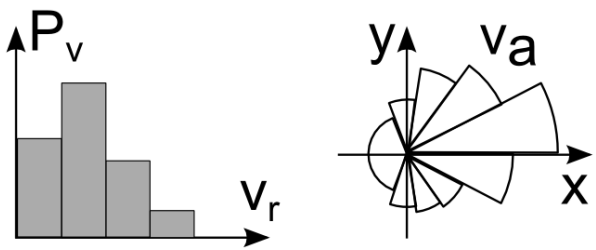
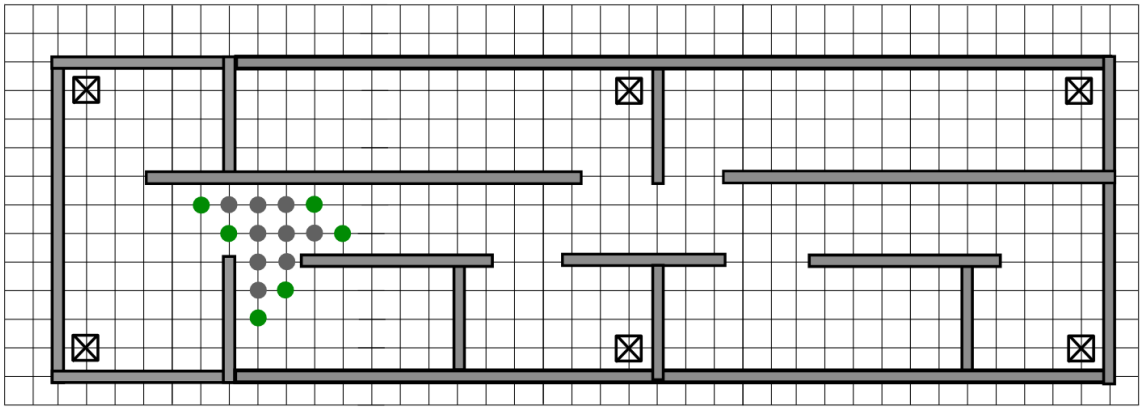


Discrete Bayes filter: algorithm

$t = 2$

1. initialization
2. prognosis
3. update
4. location estimation

Prognosis and update



Discrete Bayes filter: algorithm

$t = 2$

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3. update
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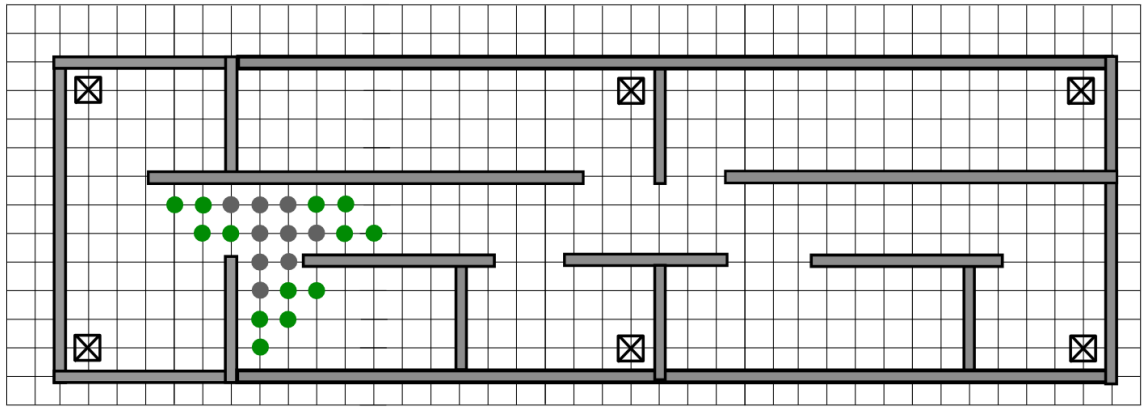
Prognosis and update



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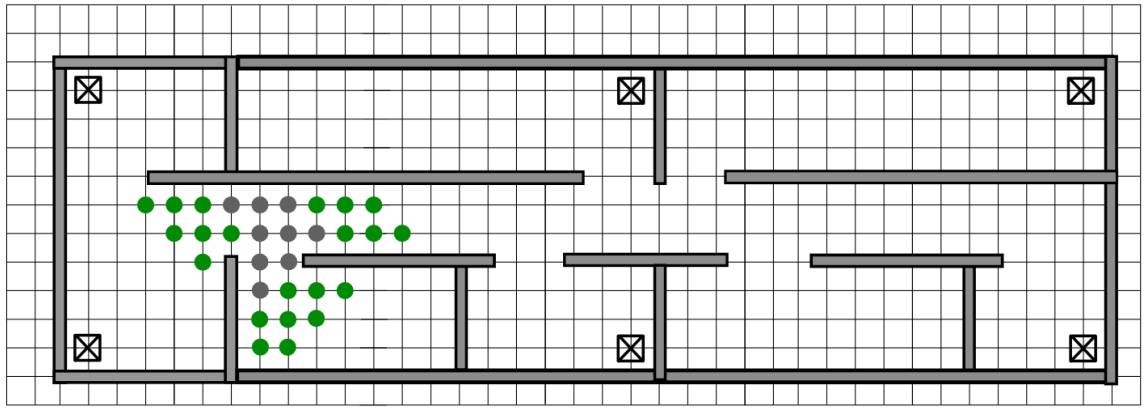

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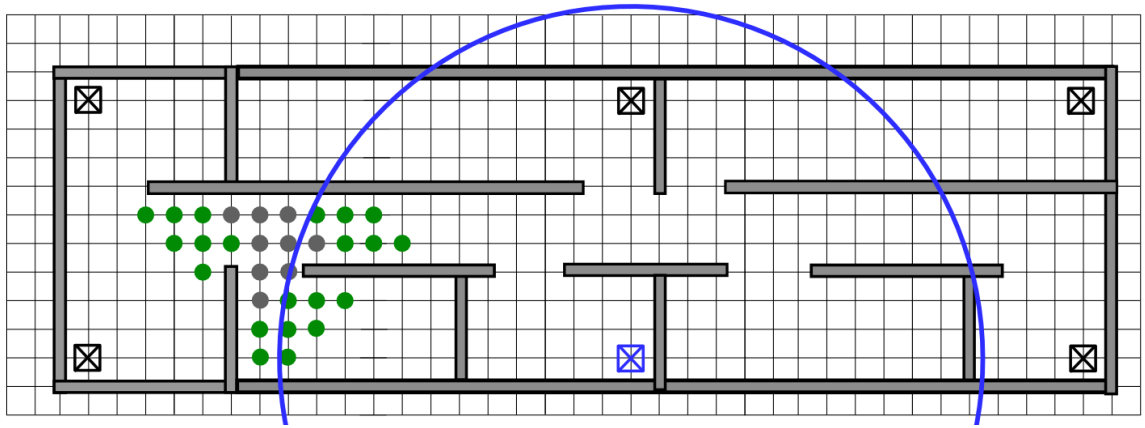

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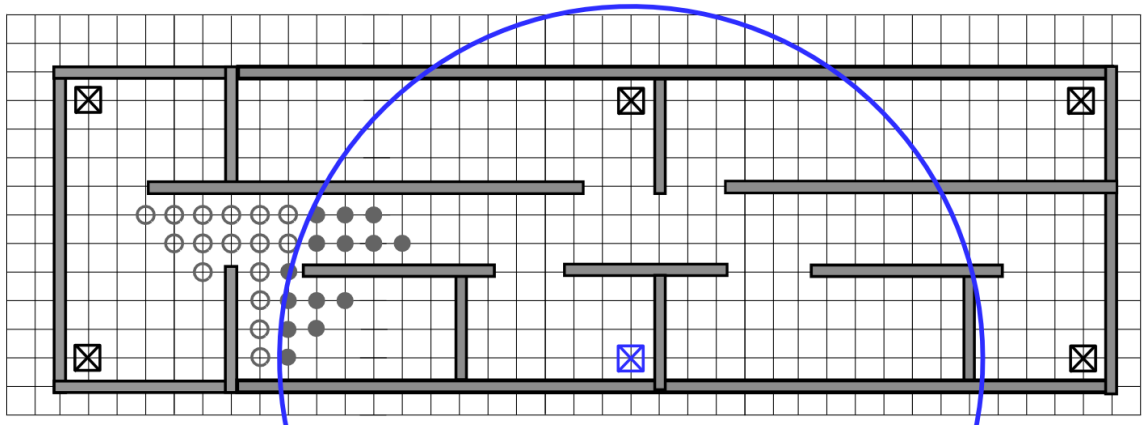

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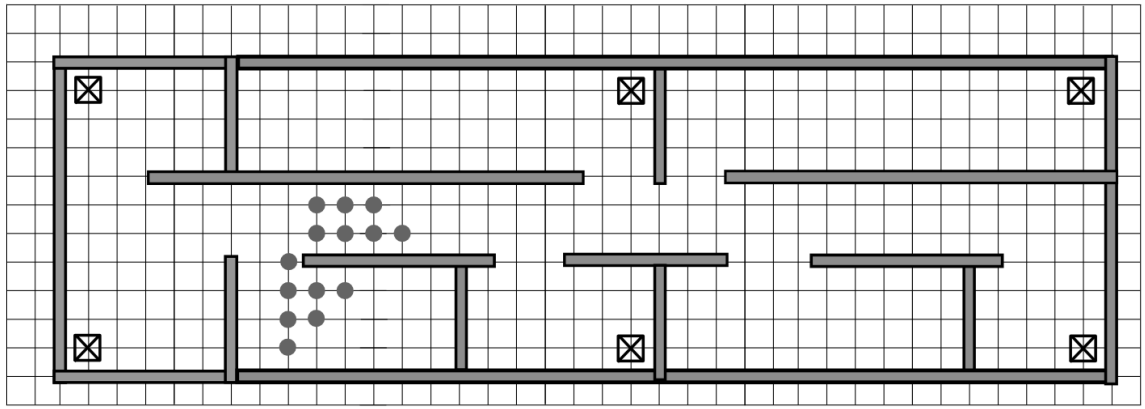
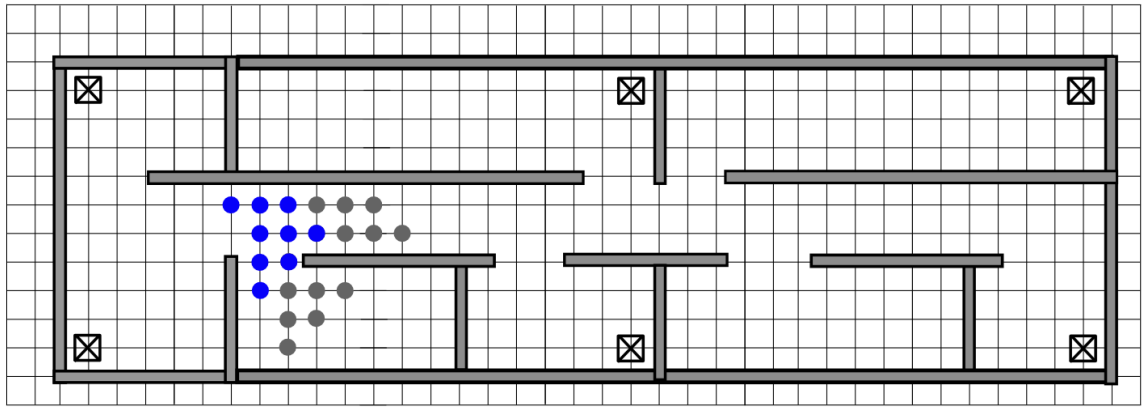


1. Prior probabilities estimation $P(\mathbf{x}_{i,t}|\mathbf{y}_{1\ldots t-1})$
2. Likelihood estimation $P(\mathbf{y}_t|\mathbf{x}_{t,i})$
   - distribution of distance measurements error
   - RSS map
3. Posterior probabilities estimation $P(\mathbf{x}_{t,i}|\mathbf{y}_{1\ldots t}) = \frac{P(\mathbf{y}_t|\mathbf{x}_{t,i})P(\mathbf{x}_{t,i}|\mathbf{y}_{1\ldots t-1})}{P(\mathbf{y}_t)}$

Discrete Bayes filter: algorithm

$t = 2$



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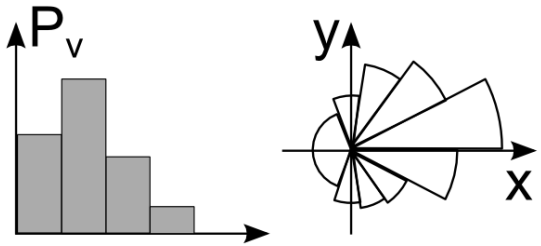

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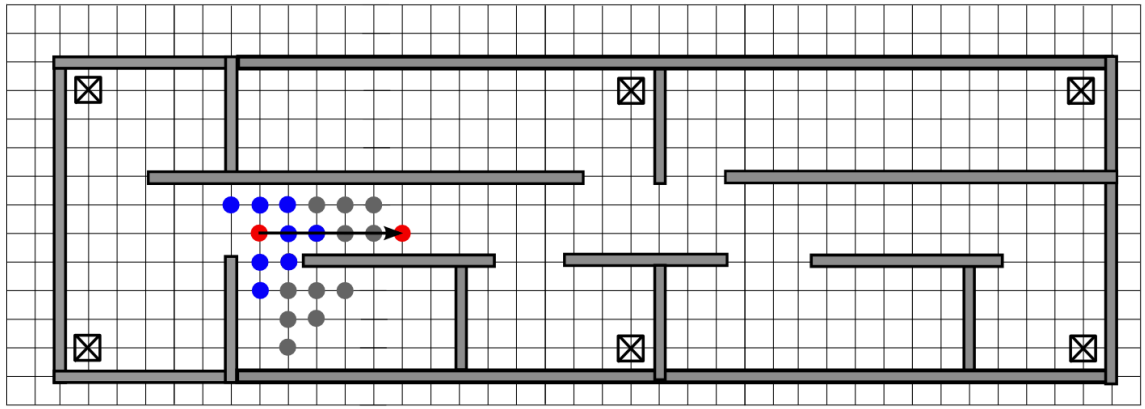

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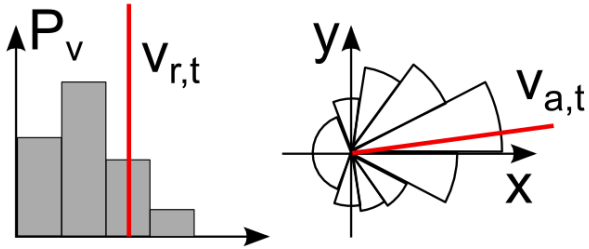

$$P(\mathbf{x}_{i,t}) \approx \eta \sum_{j=0}^{N_{t-1}} P(v_{i,j})$$
$$P(v_{i,j}) \approx P_{v_r} \cdot P_{v_a}$$

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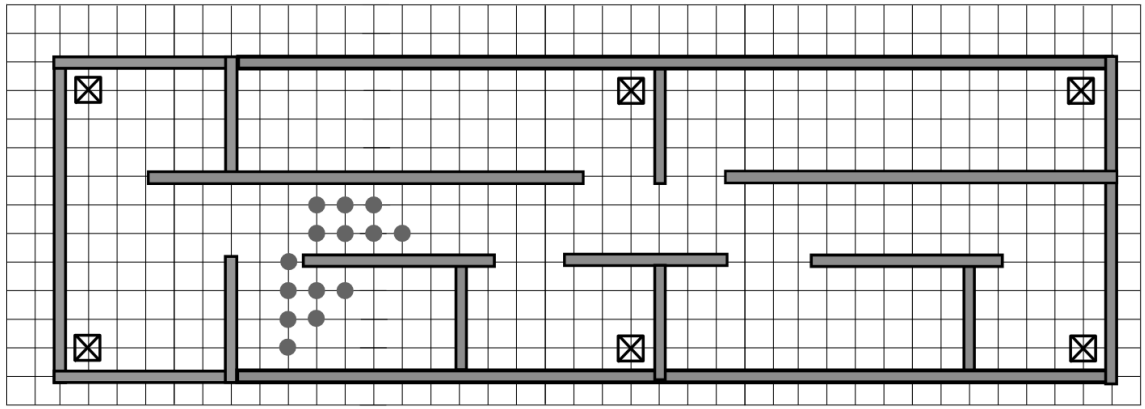

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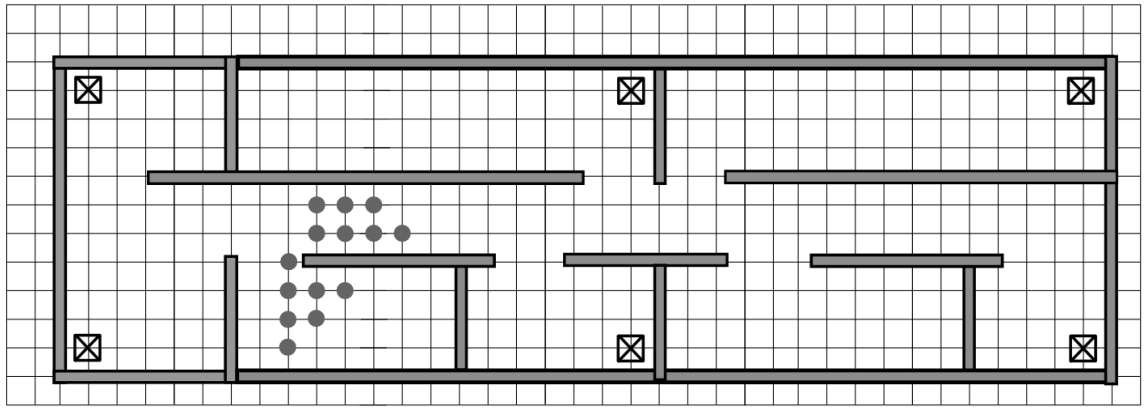

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