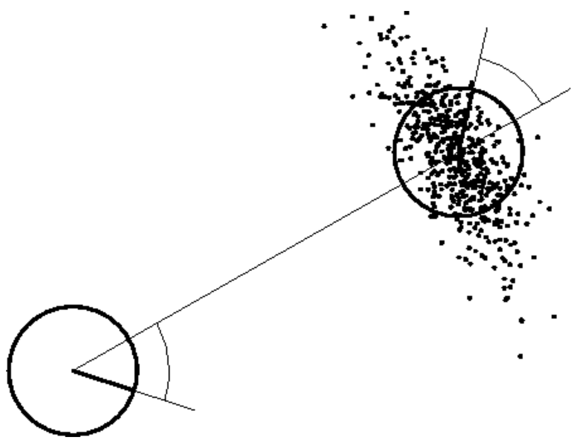
Mobile Robot Localization

- Each particle is a potential pose of the robot

- We use the motion model of the robot in the prediction step

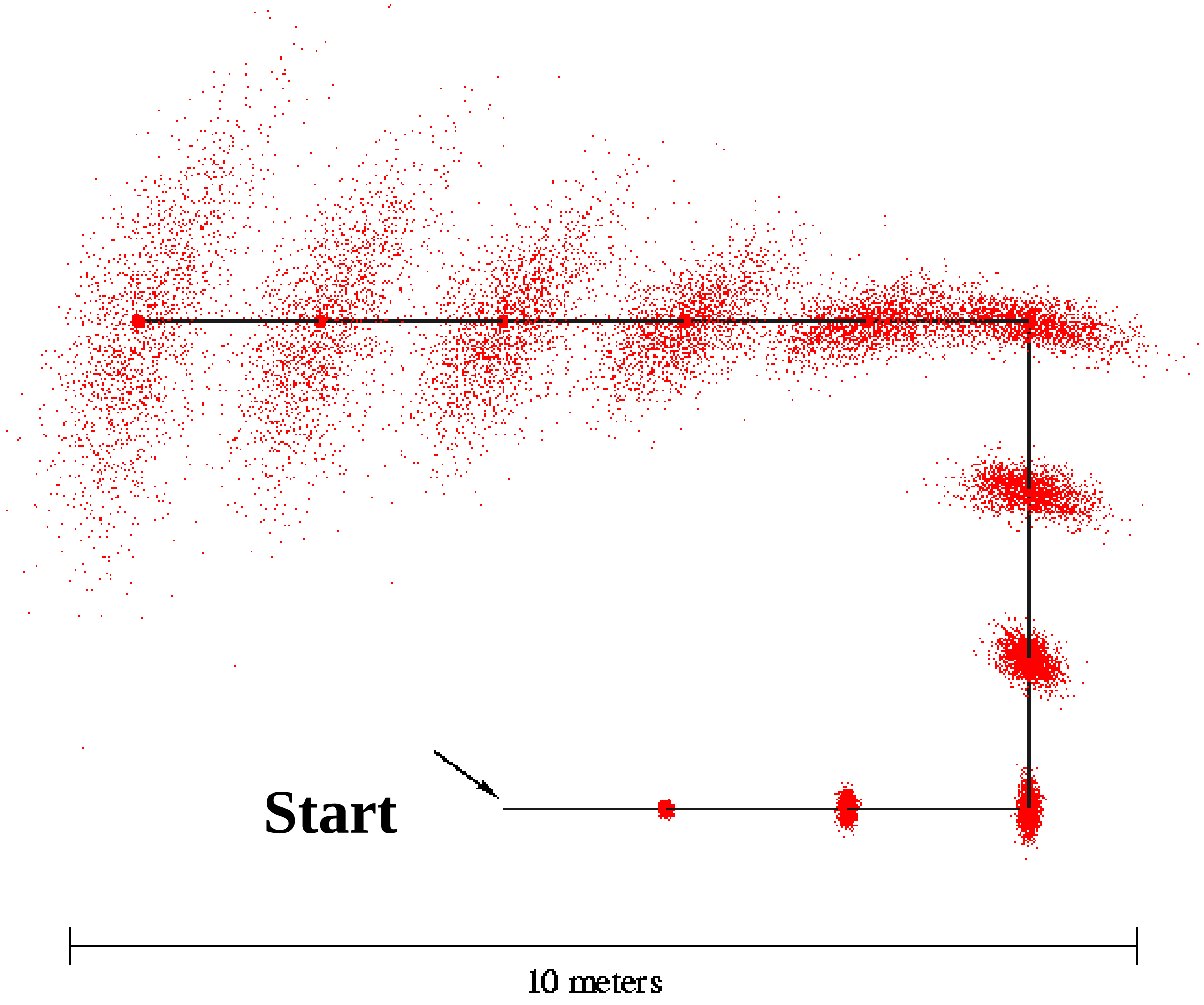
- The observation model is used to compute the importance weight in the correction step

Motion Model Reminder

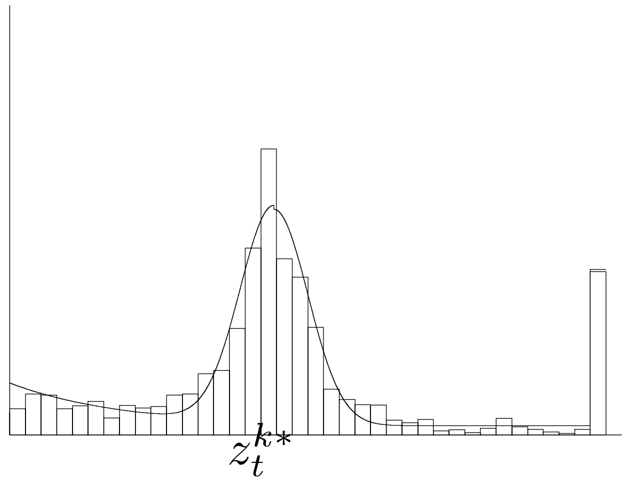


- Uncertainty in the translation of the robot: Gaussian over the traveled distance
- Uncertainty in the rotation of the robot: Gaussians over initial and final rotation
- For each particle, draw a new pose by sampling from these three individual normal distributions

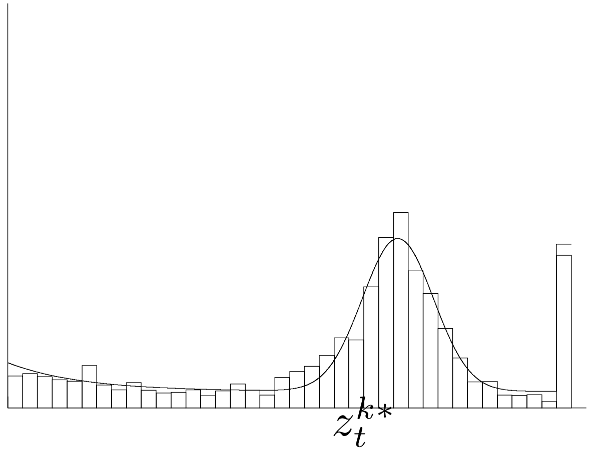
Motion Model Reminder

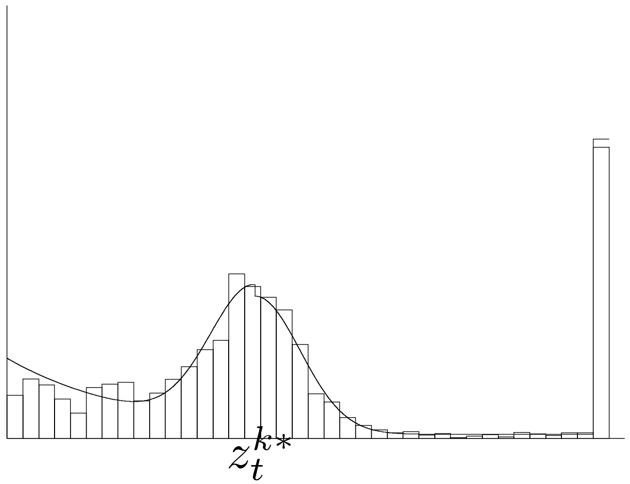


Proximity Sensor Model Reminder

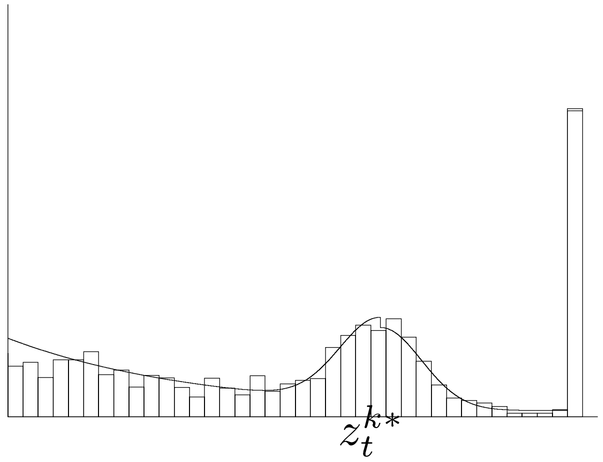


Laser





Sonar



300cm

400cm

Robot Localization using Particle Filters (1)

- Each particle is a potential pose of the robot

- The set of weighted particles approximates the posterior belief about the robot’s pose (target distribution)

Robot Localization using Particle Filters (2)

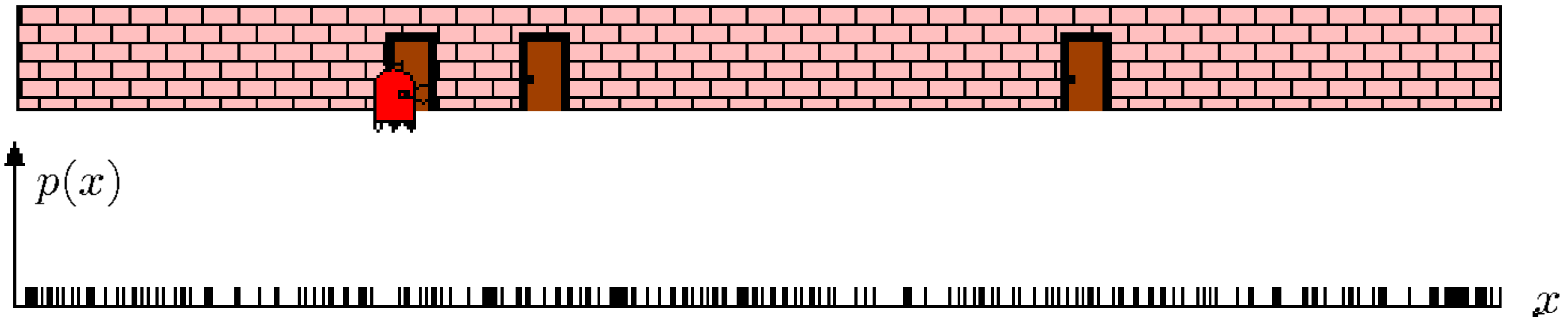
- Particles are drawn from the motion model (proposal distribution)
- Particles are weighted according to the observation model (sensor model)
- Particles are resampled according to the particle weights

Robot Localization using Particle Filters (3)

Why is resampling needed?

- We only have a finite number of particles
- Without resampling: The filter is likely to lose track of the "good" hypotheses
- Resampling ensures that particles stay in the meaningful area of the state space

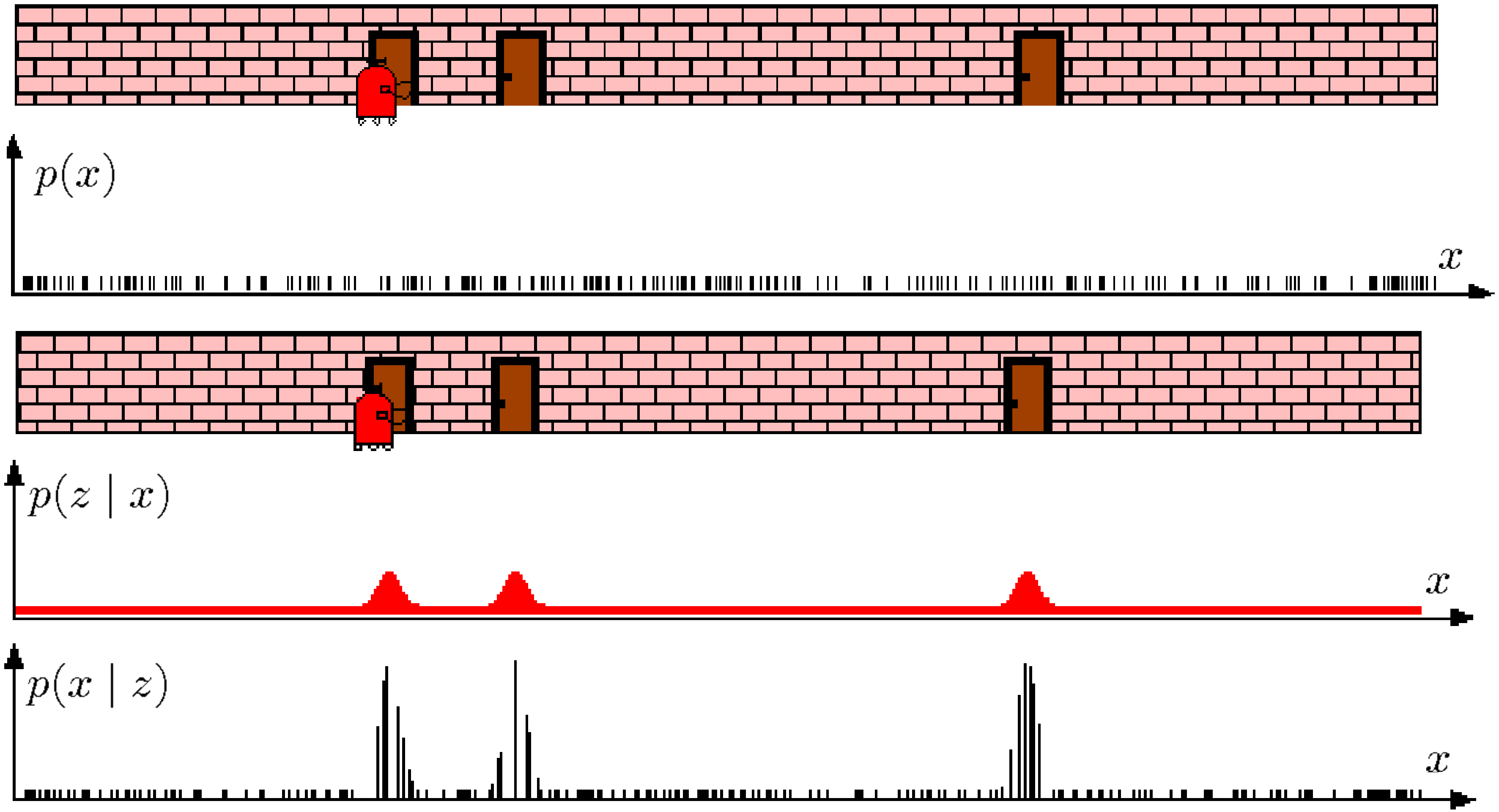
Particle Filters



Sensor Information: Importance Sampling

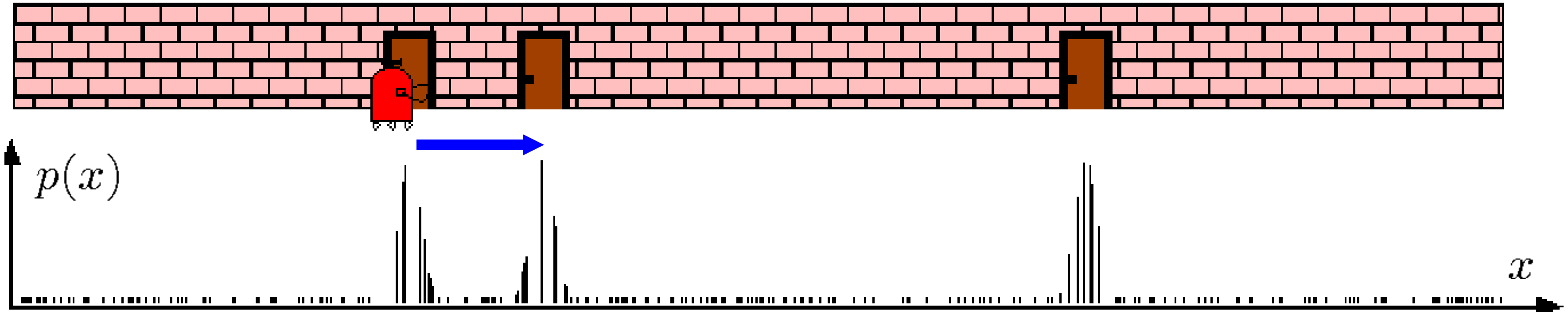
$$Bel(x) \leftarrow \alpha\, p(z|x)\, Bel^{-}(x)$$

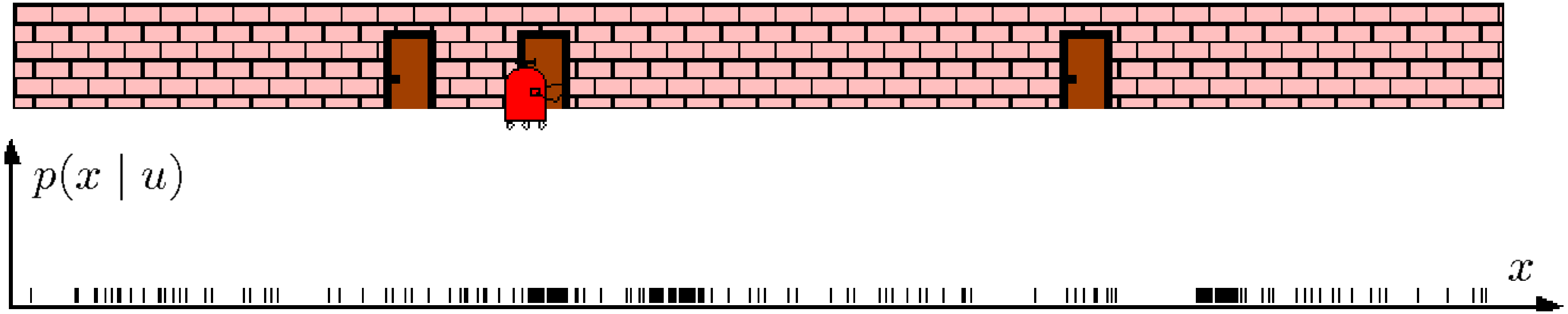
$$w \leftarrow \frac{\alpha\, p(z|x)\, Bel^{-}(x)}{Bel^{-}(x)} = \alpha\, p(z|x)$$



Robot Motion

$$Bel^-(x) \leftarrow \int p(x \mid u, x')\, Bel(x')\, \mathrm{d}x'$$





Sensor Information: Importance Sampling

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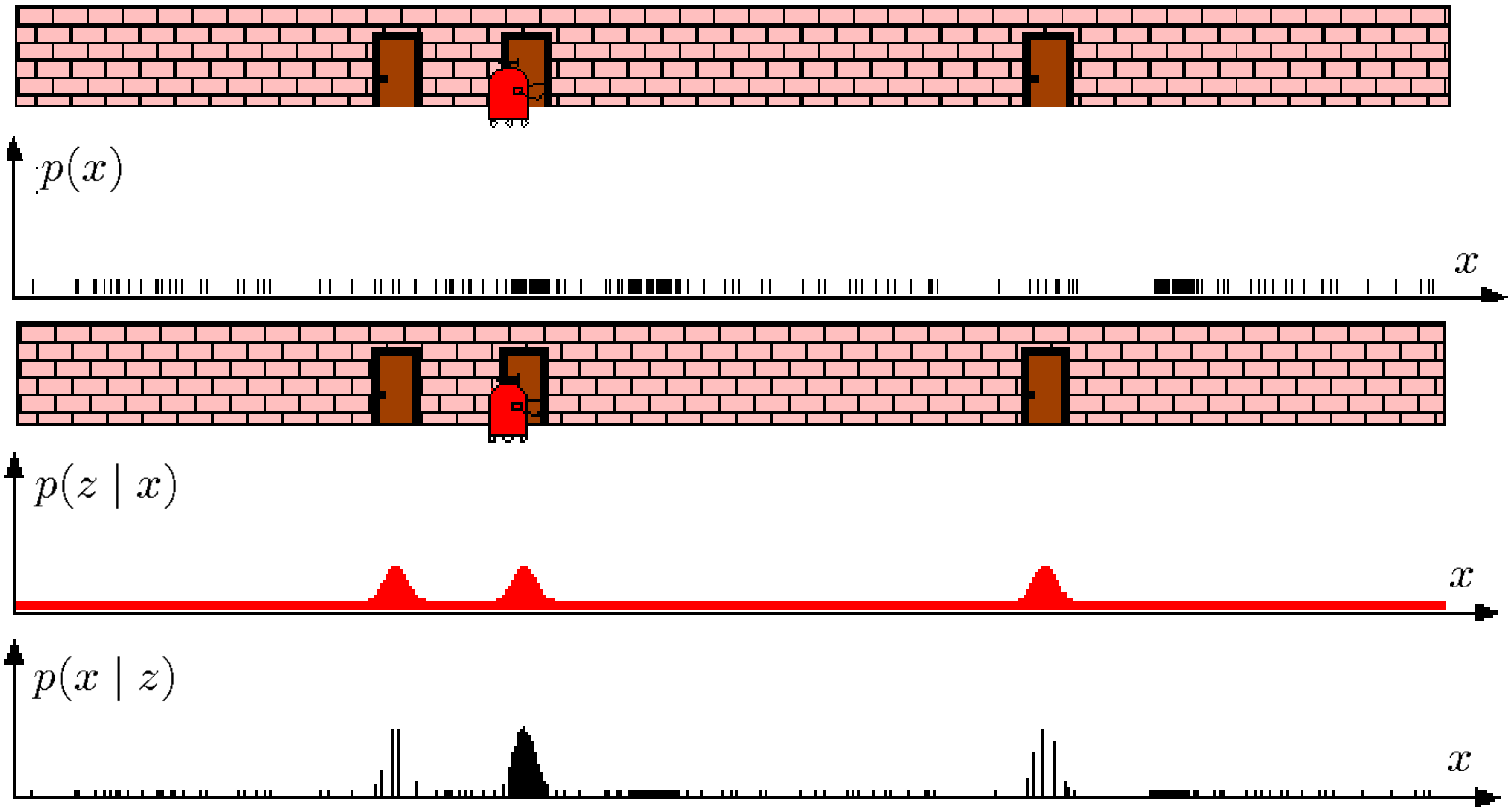
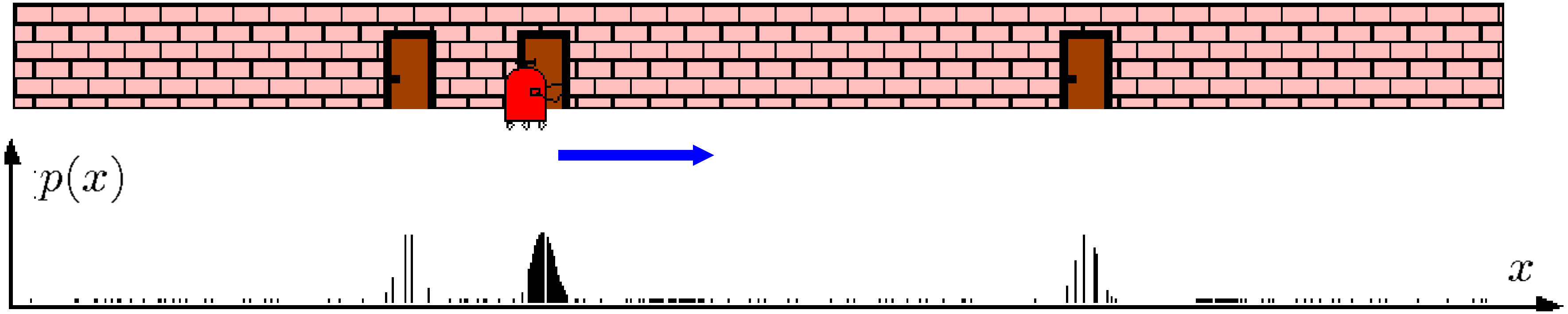
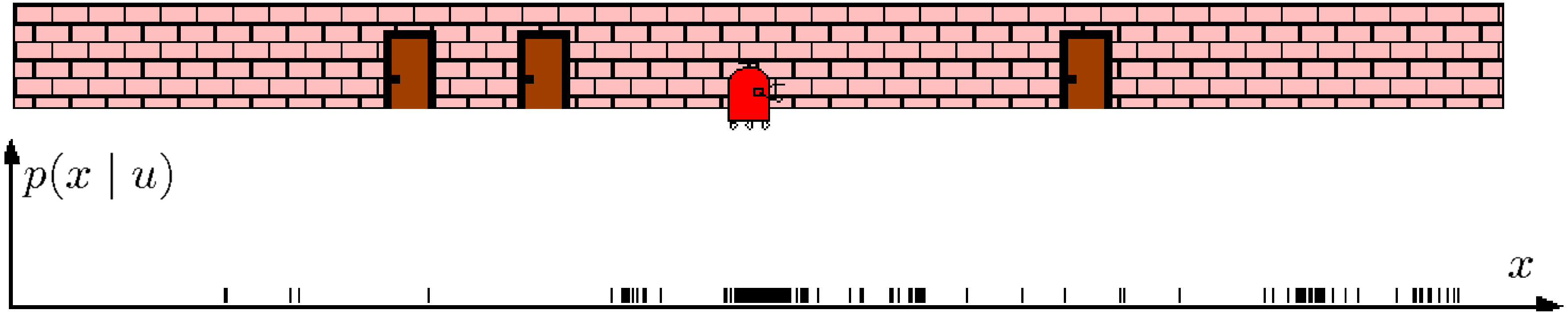


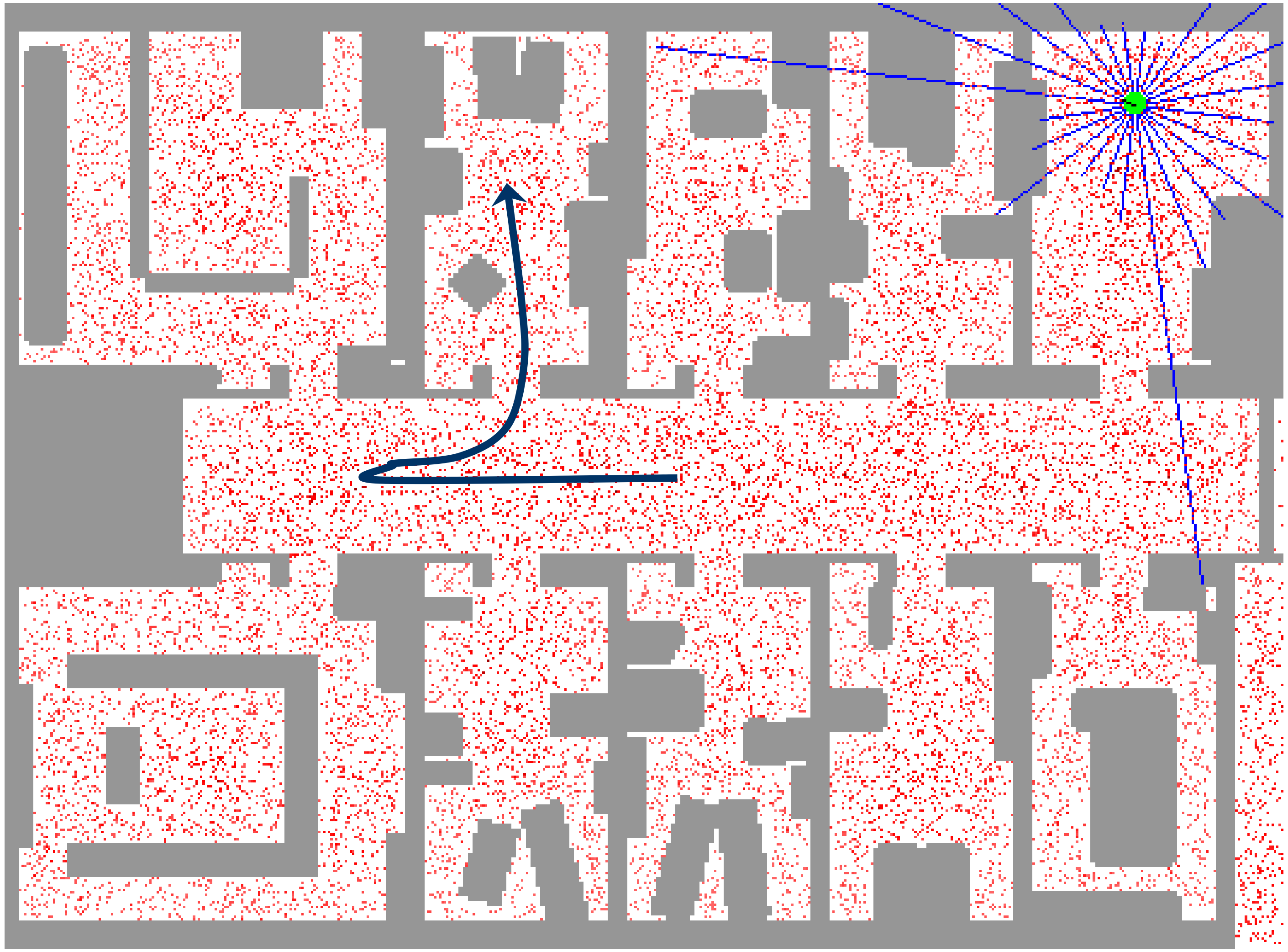
Robot Motion

$$Bel^{-}(x) \leftarrow \int p(x \mid u, x')\, Bel(x')\, \mathrm{d}x'$$

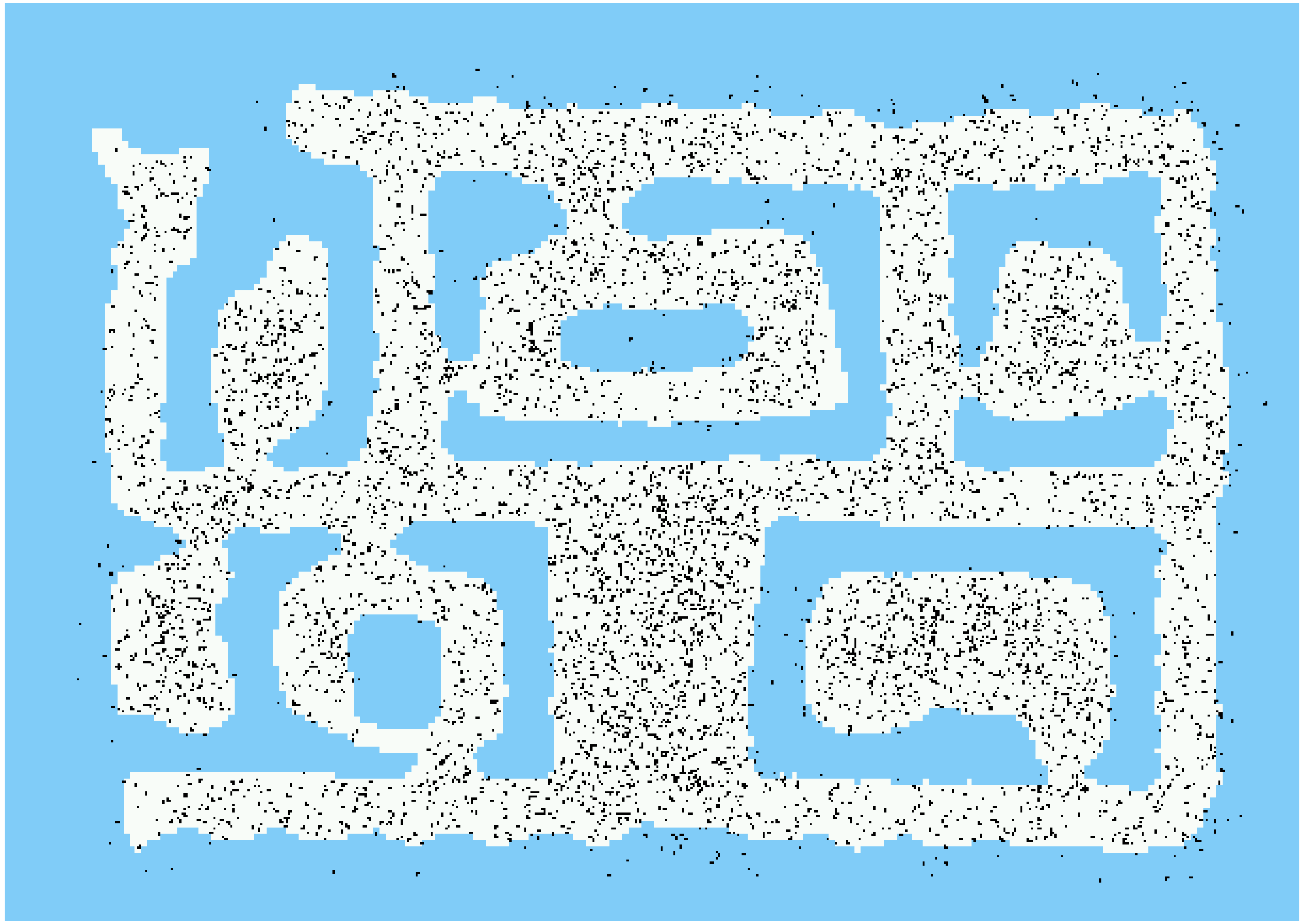




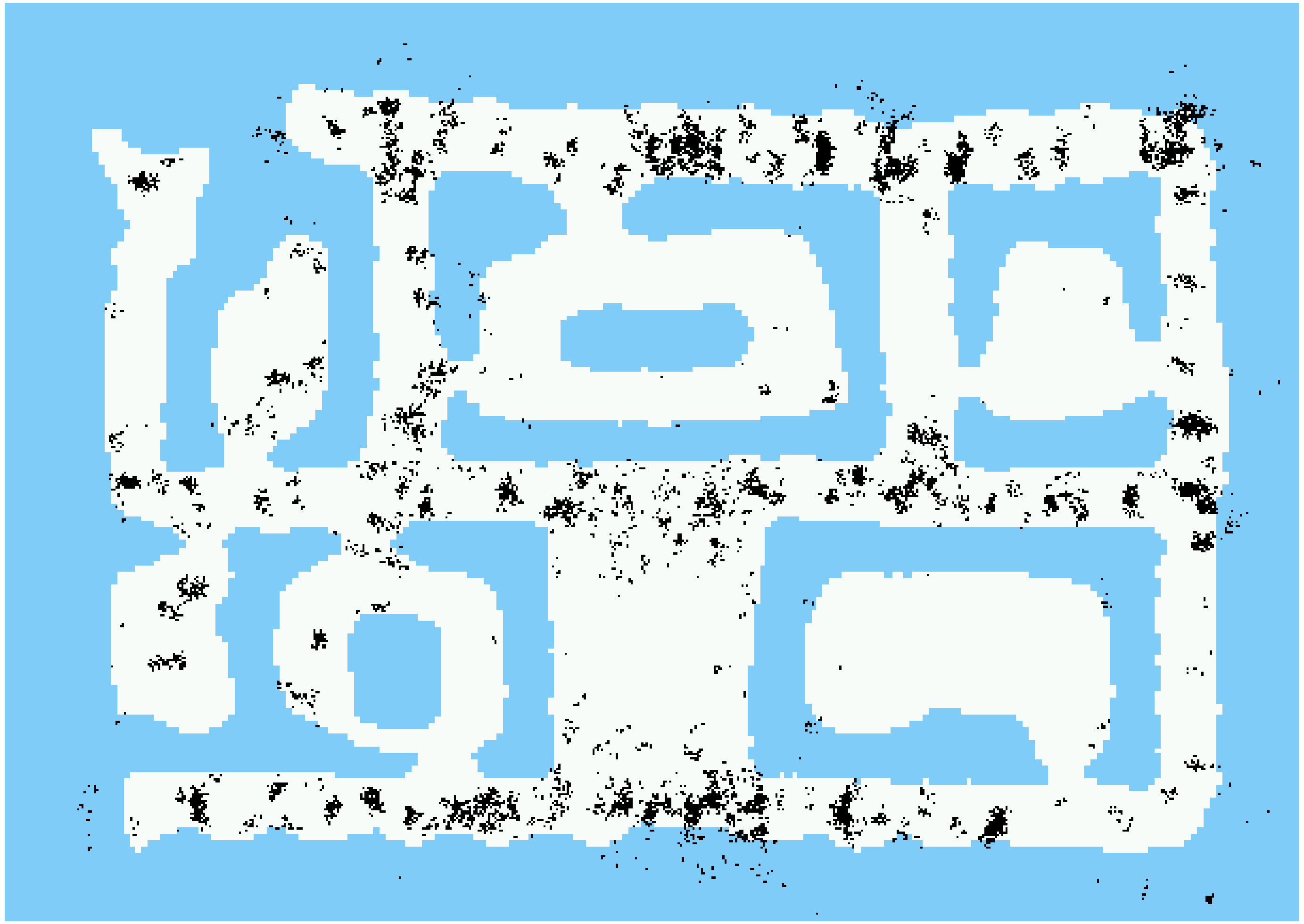
Sample-based Localization (Ultrasound)



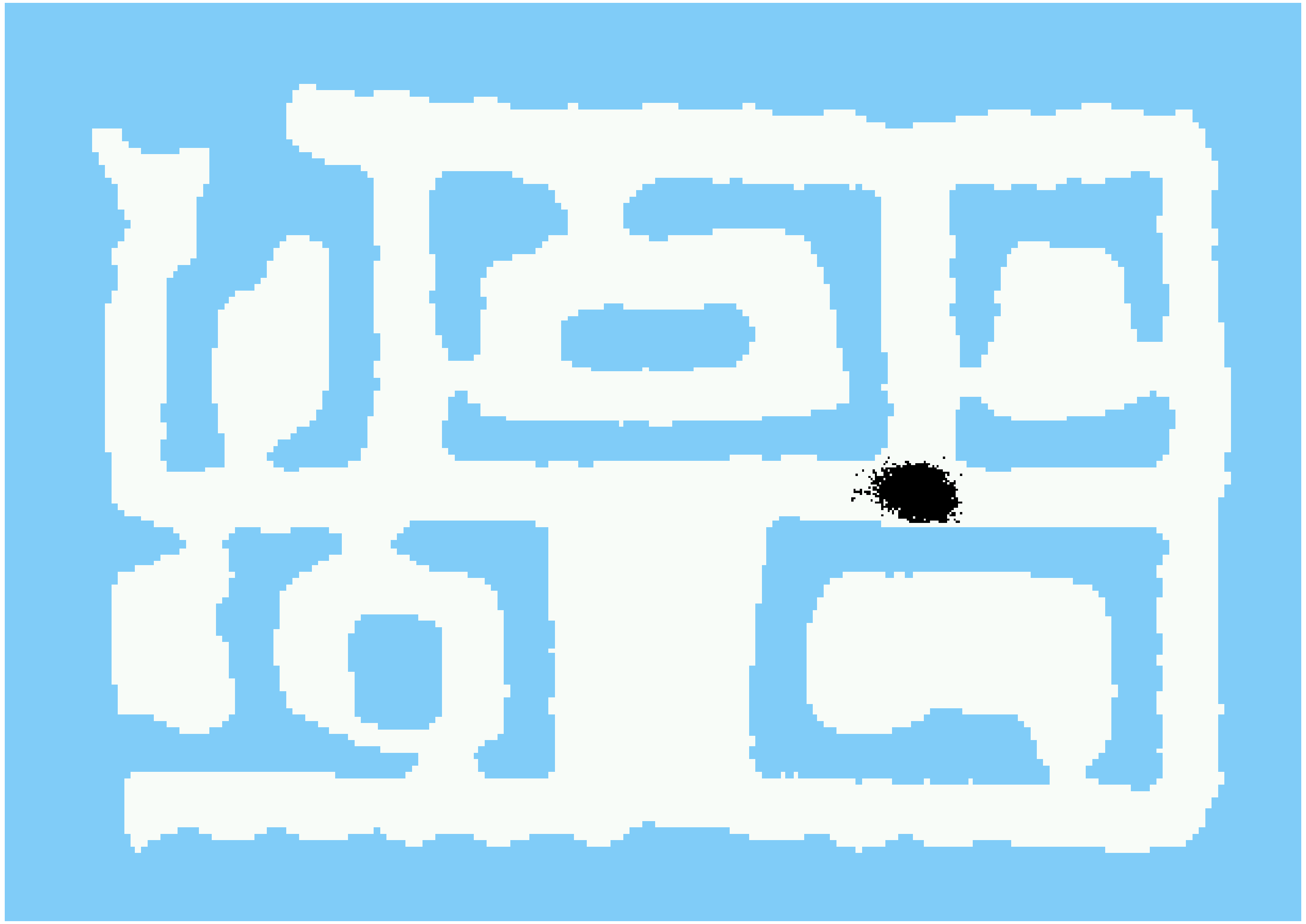
Initial Distribution



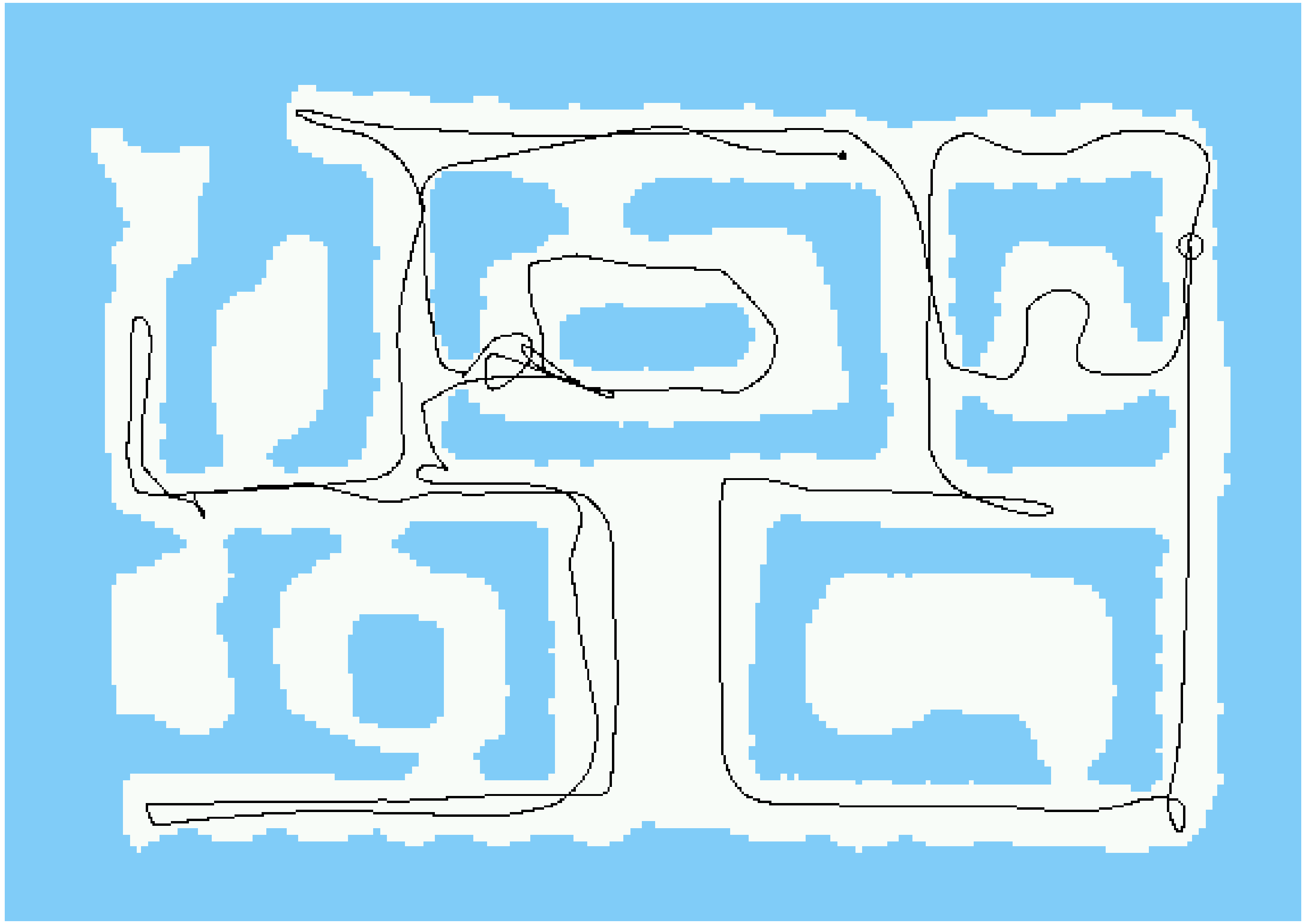
After Incorporating Ten Ultrasound Scans



After Incorporating 65 Ultrasound Scans



Estimated Path



Limitations

- The approach described so far is able
  - to track the pose of a mobile robot and
  - to globally localize the robot

- How can we deal with localization errors (i.e., the kidnapped robot problem)?

Approaches

- Randomly insert a fixed number of samples with randomly chosen poses
- This corresponds to the assumption that the robot can be teleported at any point in time to an arbitrary location
- Alternatively, insert such samples inverse proportional to the average likelihood of the observations (the lower this likelihood the higher the probability that the current estimate is wrong).

Summary – Particle Filter Localization

- In the context of localization, the particles are propagated according to the motion model.
- They are then weighted according to the likelihood model (likelihood of the observations).
- In a re-sampling step, new particles are drawn with a probability proportional to the likelihood of the observation.
- This leads to one of the most popular approaches to mobile robot localization