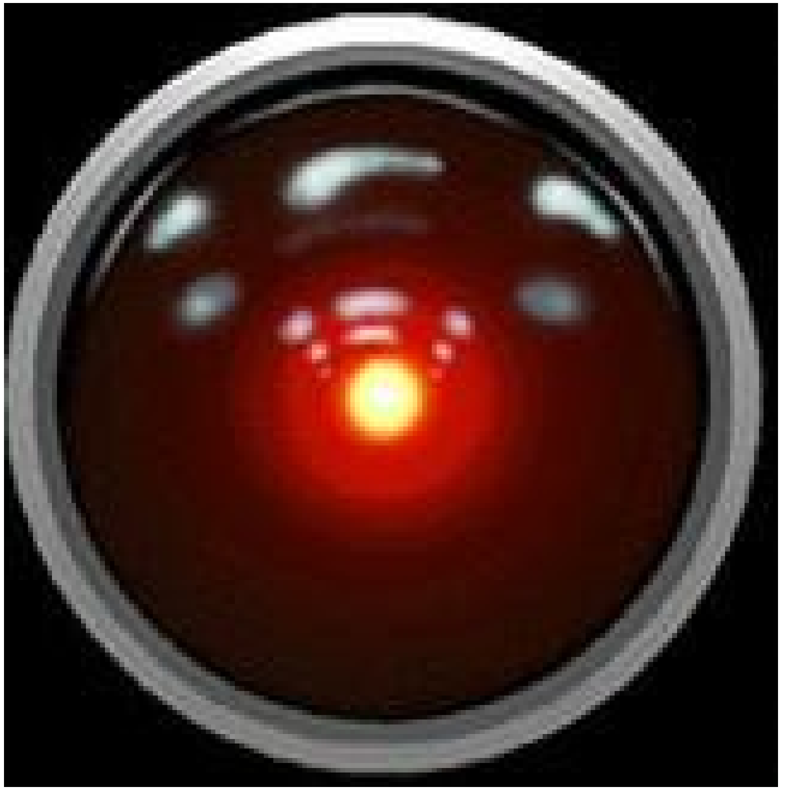
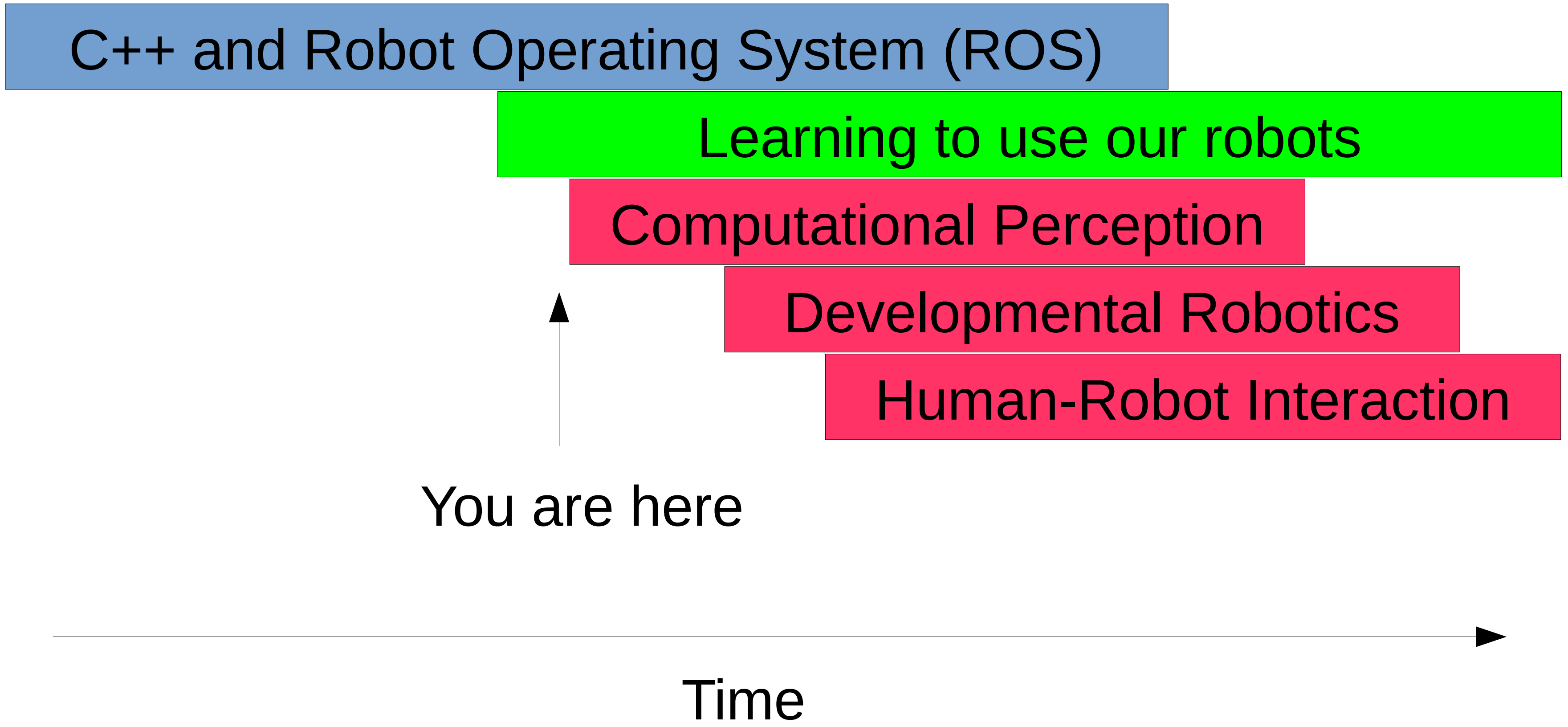


CS 378: Autonomous Intelligent Robotics

Instructor: Jivko Sinapov

http://www.cs.utexas.edu/~jsinapov/teaching/cs378/

Semester Schedule



ExploreUT

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Today

- Reading Discussions

- Where in the world is the robot?
  - a.k.a. Robot Mapping and Localization

- Overview of Homework 5

Reading Discussion

Hoffmann, Matej, and Rolf Pfeifer. "The implications of embodiment for behavior and cognition: animal and robotic case studies." arXiv preprint arXiv:1202.0440 (2012).

Hoffman, Guy. "Embodied cognition for autonomous interactive robots." Topics in cognitive science 4.4 (2012): 759-772.

Michel, Philipp, Kevin Gold, and Brian Scassellati. "Motion-based robotic self-recognition." Intelligent Robots and Systems, 2004.(IROS 2004). Proceedings. 2004 IEEE/RSJ International Conference on. Vol. 3. IEEE, 2004.

Reading Discussion

“Since the article focused on a robot with one arm, how would the robot's “understanding” sort of apply if it had multiple appendages?

Why do they dislike “kinematic models” for this?”

- Jonathan

Reading Discussion

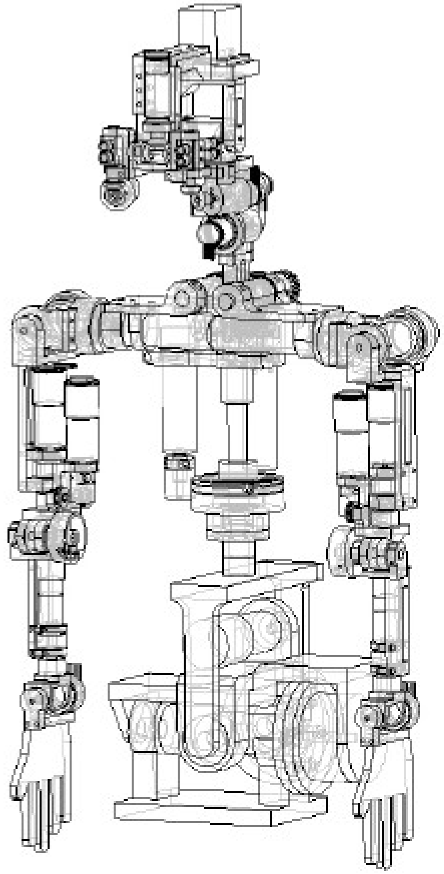


Fig. 1. Line drawing of the robot's current mechanical design.

Reading Discussion

"The robot used in the experiment, Nico, did not seem to have any means of moving its entire body from place to place. I have to wonder if a moving robot would have had the same success with the given method."

- Aylish

Reading Discussion

“... if there were multiple robots that performed the same action as a certain robot, would that robot perceive the others to be itself? And if it did so, how would this impact its "thinking" when the others no longer behaved in the same way as itself? What possible methods are there to avoid crashes or failures that could result from this?

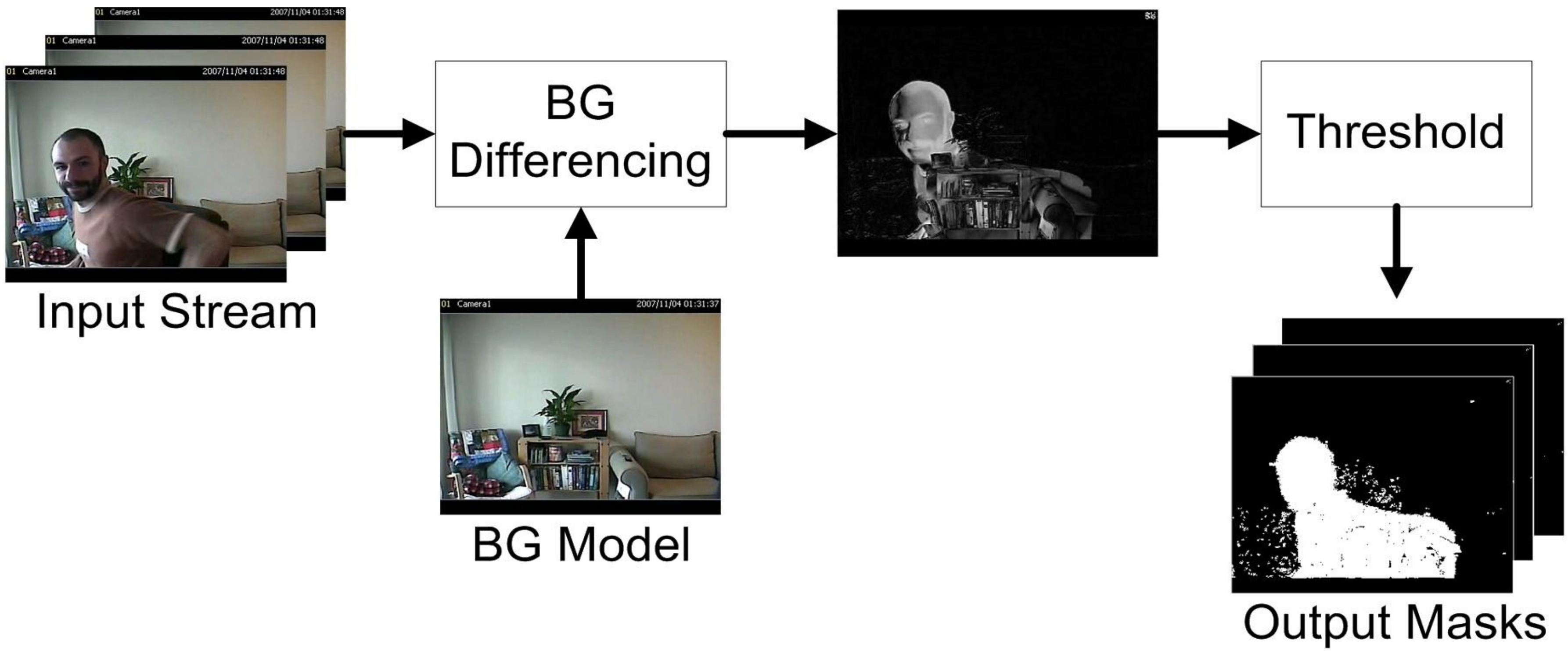
- Justin

Reading Discussion

“What is image differencing?”

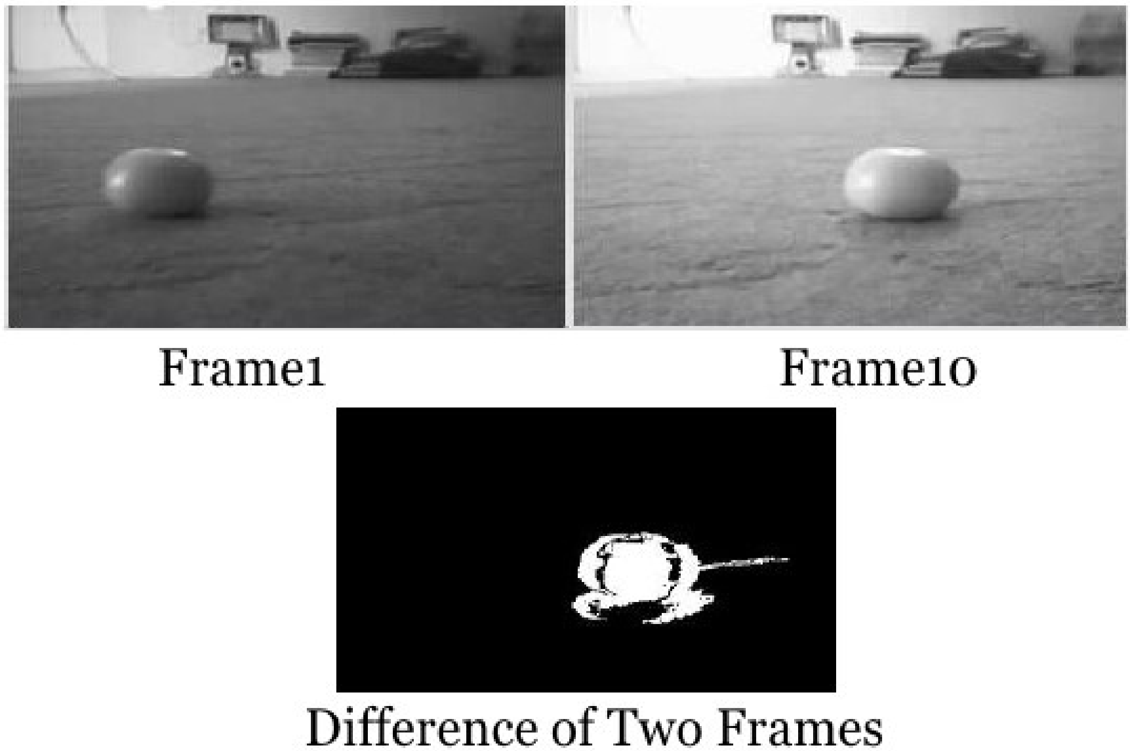
- Kathryn

Reading Discussion



[http://dparks.wdfiles.com/local--files/background-subtraction/FrameDifferencing.jpg]

Reading Discussion



http://image.slidesharecdn.com/rti3final-120605105222-phpapp01/95/real-time-object-tracking-14-728.jpg?cb=1338893663

Reading Discussion

“A question I have is: how long is the time delay and how does it compare to the time delay that humans experience when learning about our own self-awareness during infancy? Surely it should be much faster for the robot with all that processing power.”

- Hector

Reading Discussion

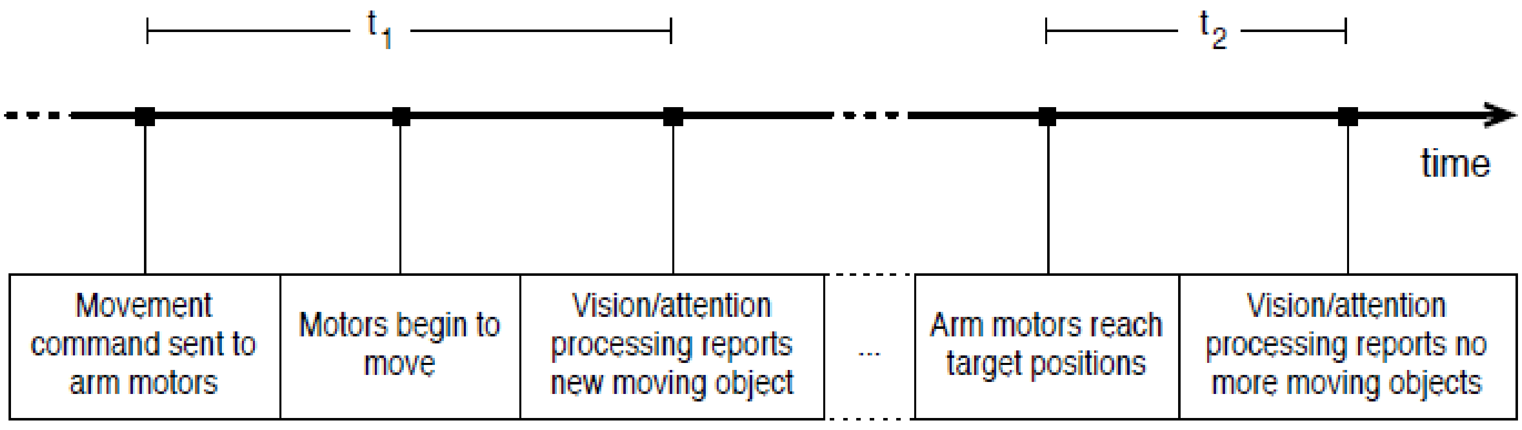


Fig. 4. Timeline showing relevant events for the measurement of t_1 and t_2.

Reading Discussion

Further reading:

- Stoytchev, Alexander. "Self-detection in robots: a method based on detecting temporal contingencies." Robotica 29.01 (2011): 1-21.
- Hoffmann, Matej, et al. "Body schema in robotics: a review." Autonomous Mental Development, IEEE Transactions on 2.4 (2010): 304-324.

Readings for this week

Rekleitis, I., “A Particle Filter Tutorial for Mobile Robot Localization”

Burgard, Wolfram, et al. "Experiences with an interactive museum tour-guide robot." Artificial intelligence 114.1 (1999): 3-55.

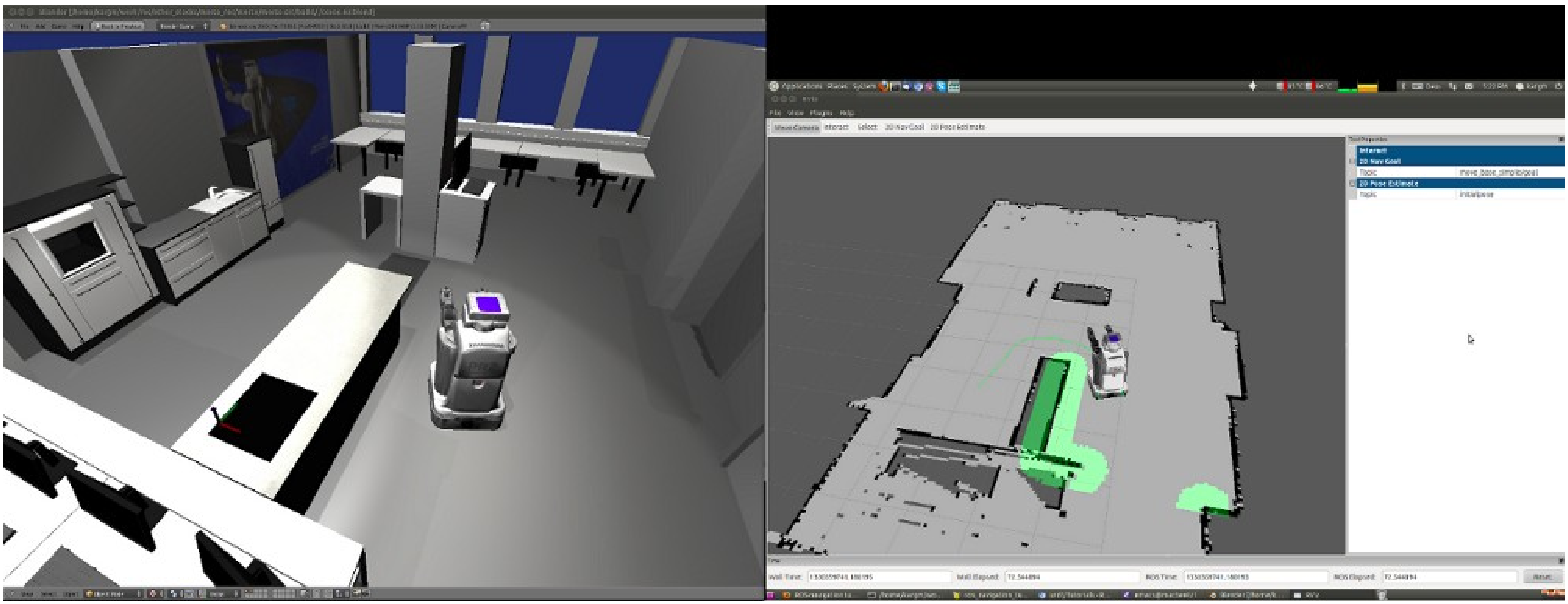
Ch.1, “Probability and Random Variables” from “Introduction to Random Signals and Applied Kalman Filtering”

Robot Localization

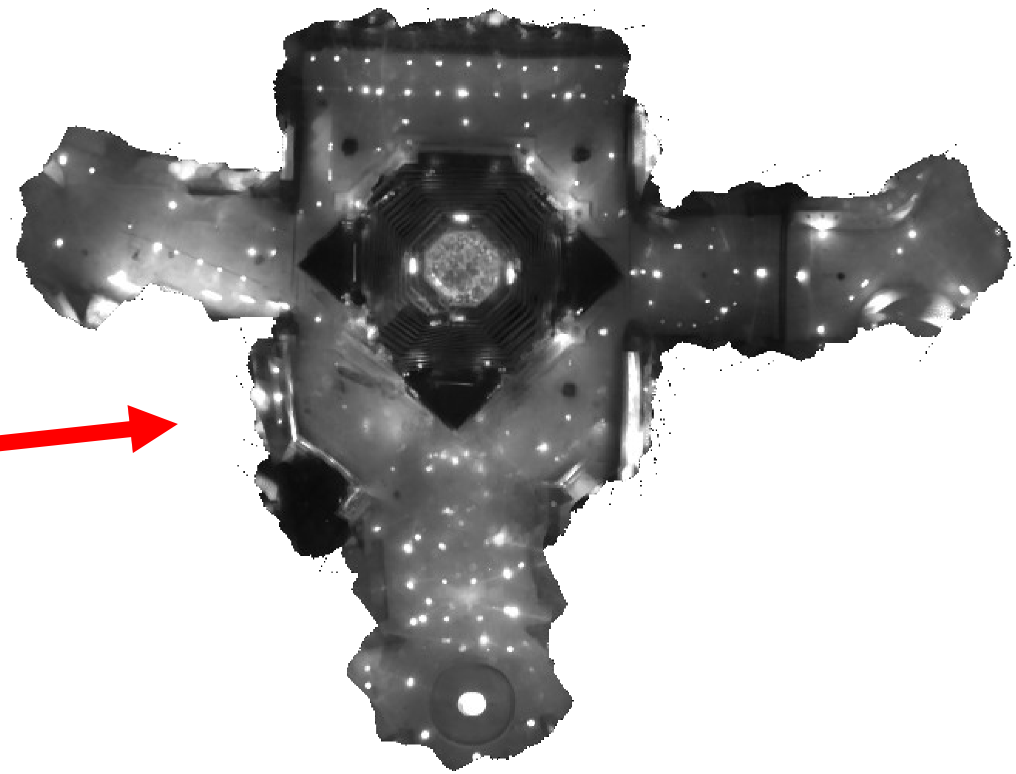
Robot Localization

- Main problems:
  - How should the robot represent the map of the world?
  - How should the robot use existing sensory data, combined with knowledge of its own movements, to figure out where it is in the map?

2D Laser Scan for Localization



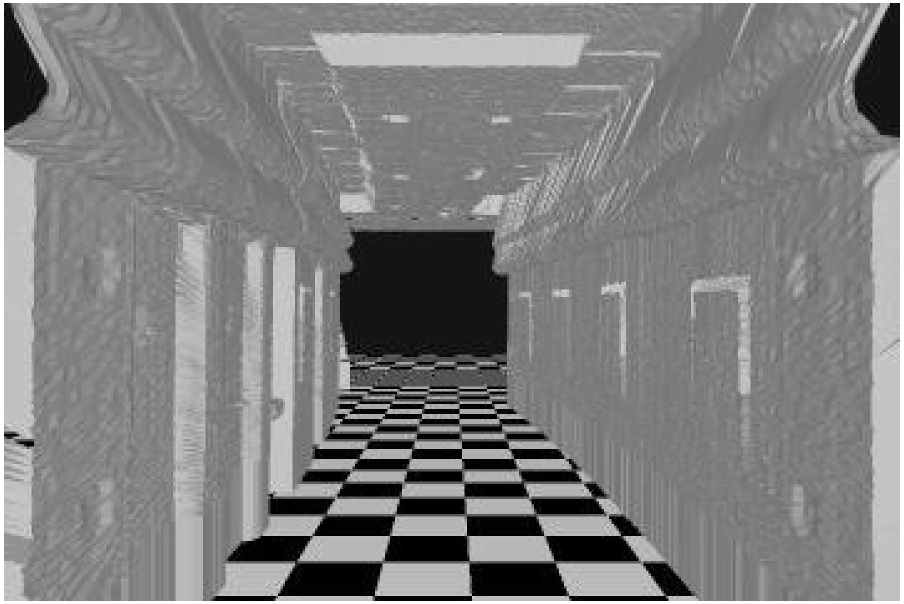
Using Ceiling Maps for Localization



3D Laser Mapping

http://www.cc.gatech.edu/aimosaic/robot-lab/research/3d/

3D mapping

[Michael Kaess, Georgia Tech]

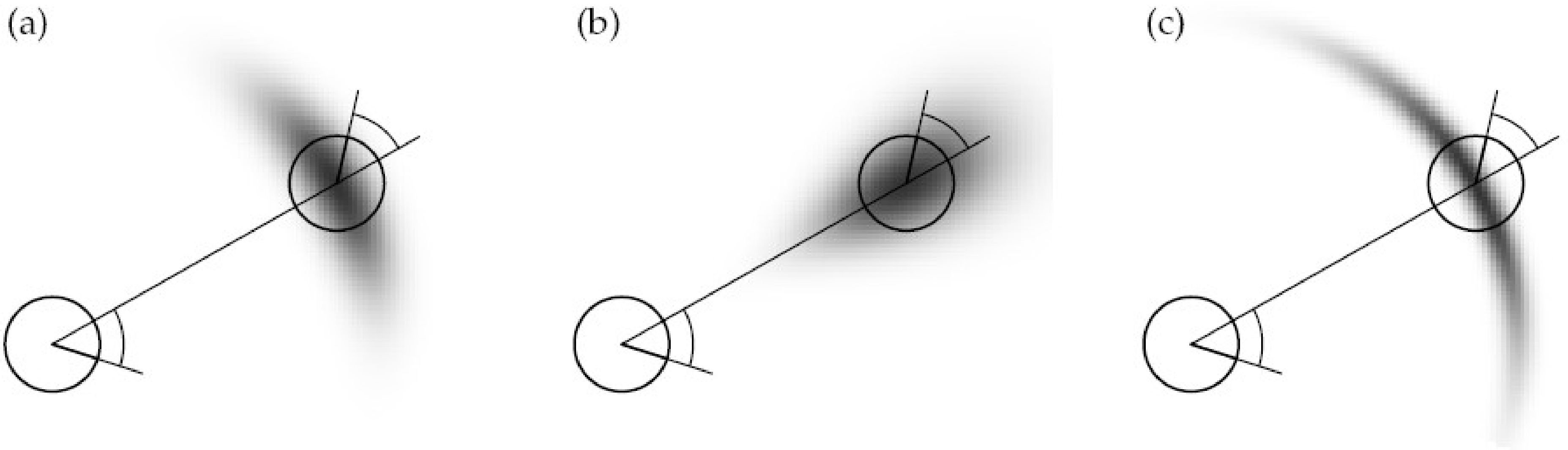
3D mapping

[Michael Kaess, Georgia Tech]

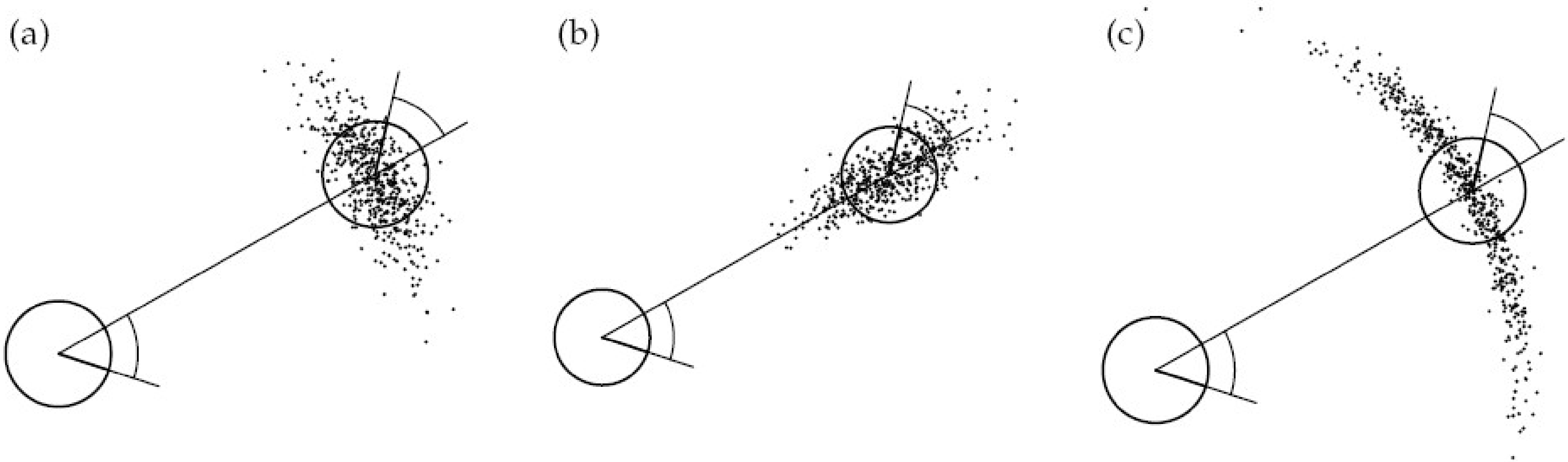
Robot Localization

Why is it not enough to simply keep track of the robot's movements relative to the starting point in the map?

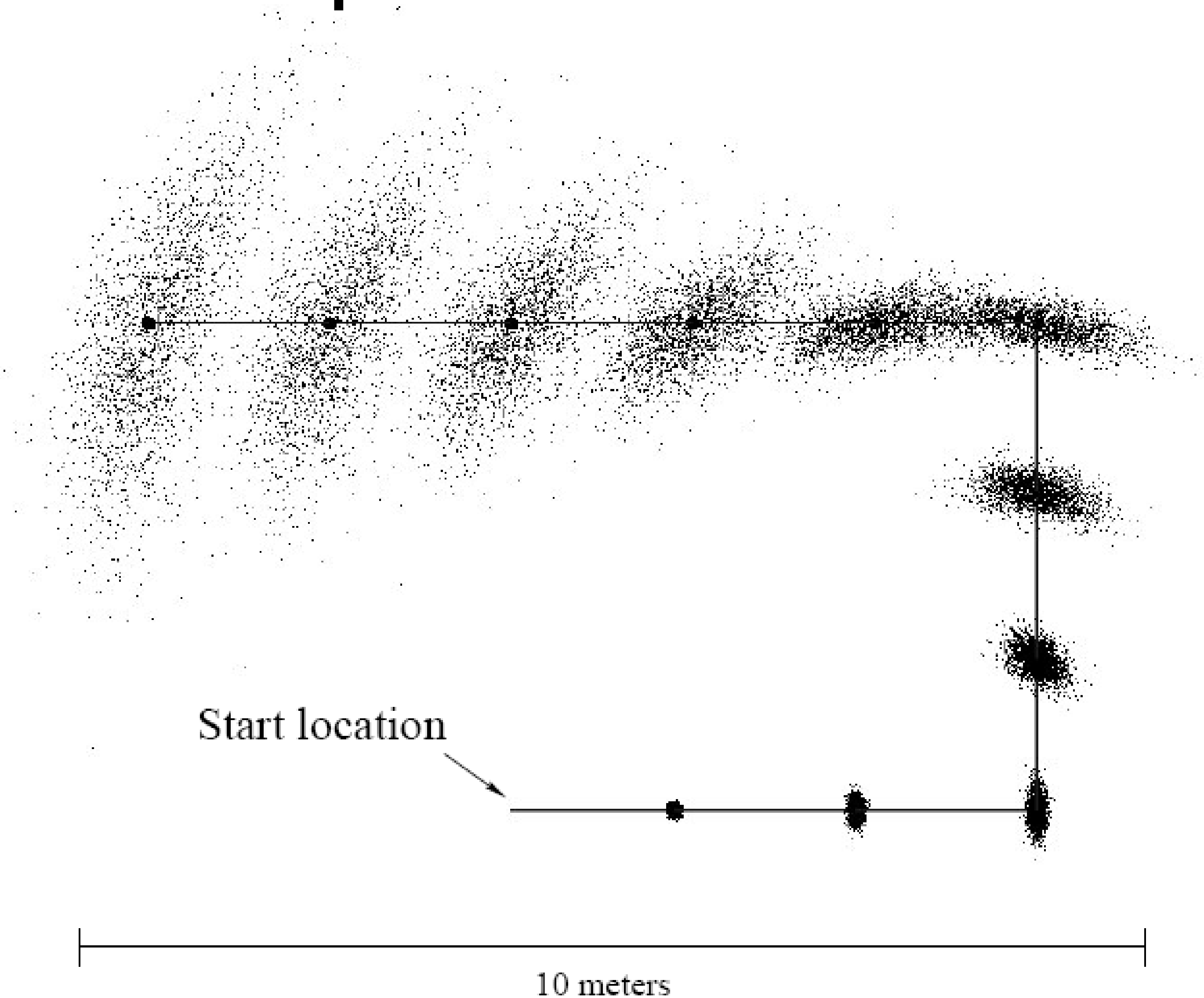
Odometry Motion Model



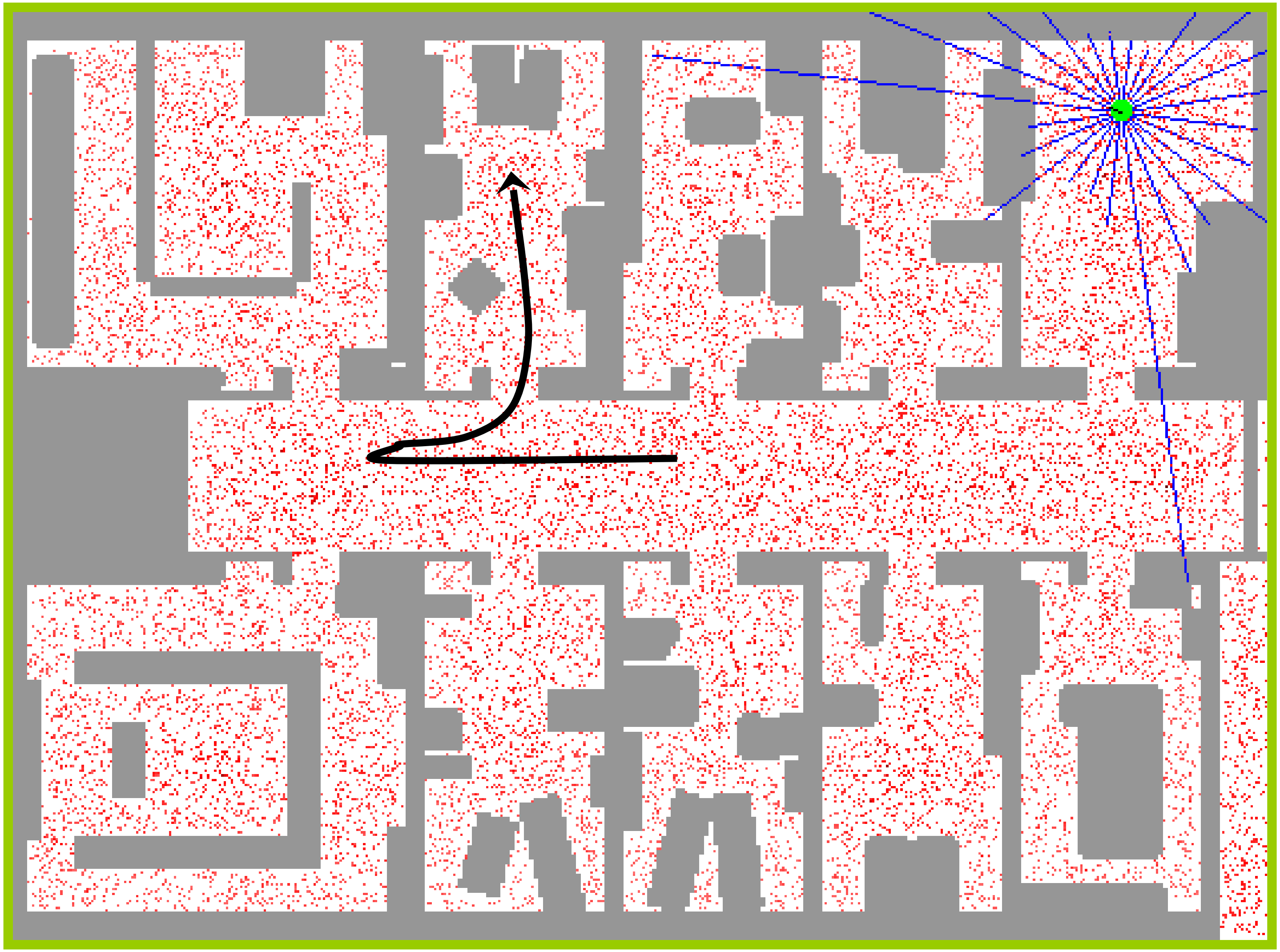
Sampling From the Odometry Model

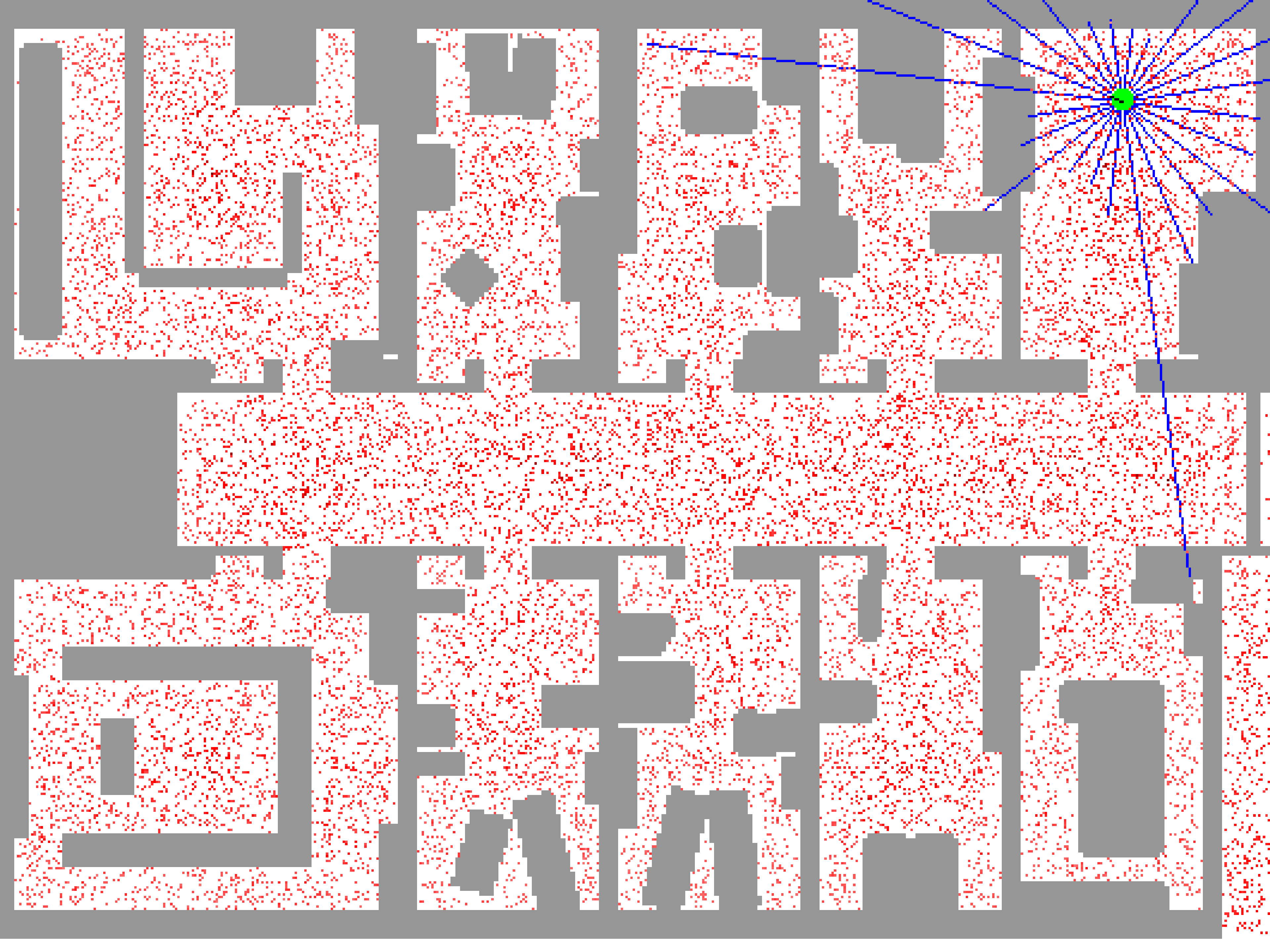


Uncertainty accumulates after multiple movements



Localization using Sonar





Example

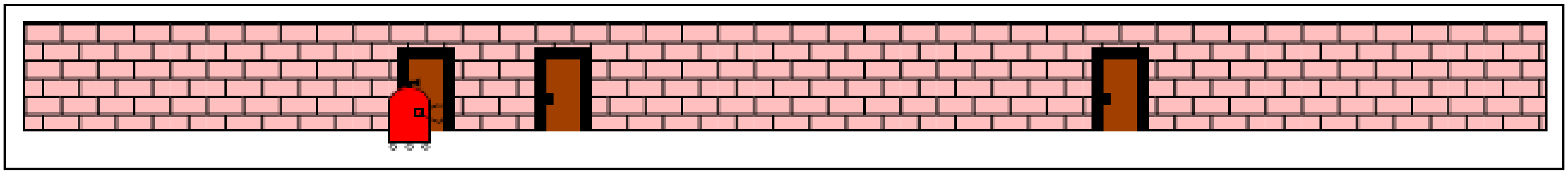
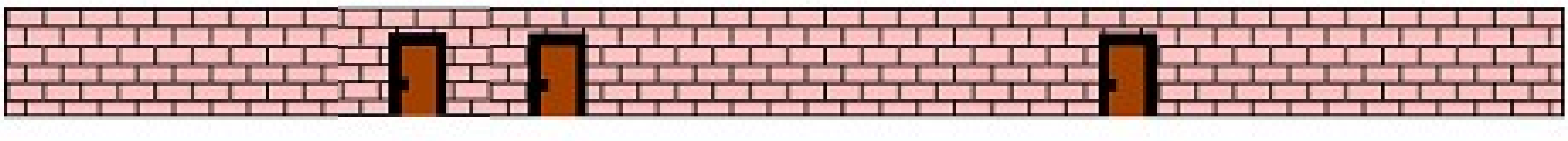
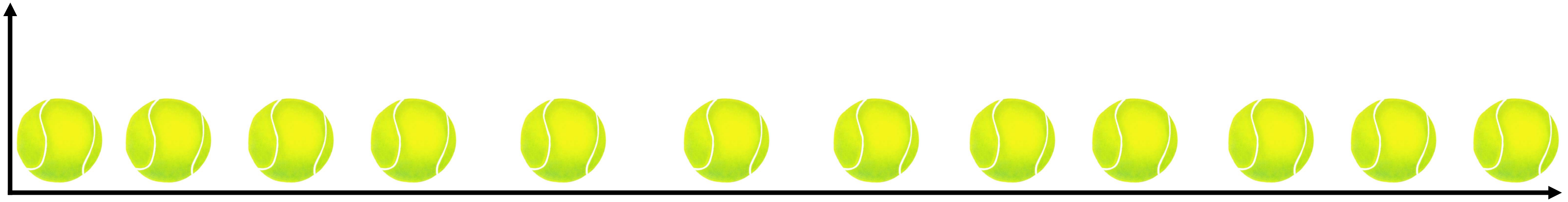


Figure 7.4 Example environment used to illustrate mobile robot localization: One-dimensional hallway environment with three indistinguishable doors. Initially the robot does not know its location except for its heading direction. Its goal is to find out where it is.

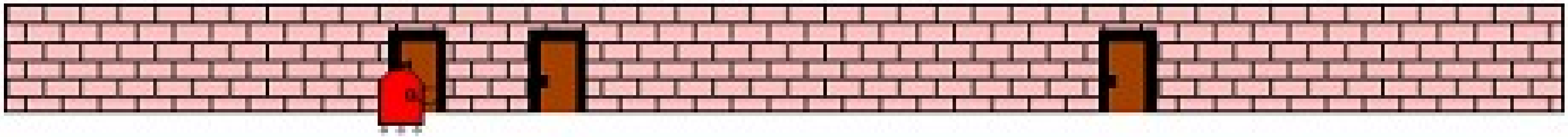
[Thrun, Burgard & Fox (2005)]

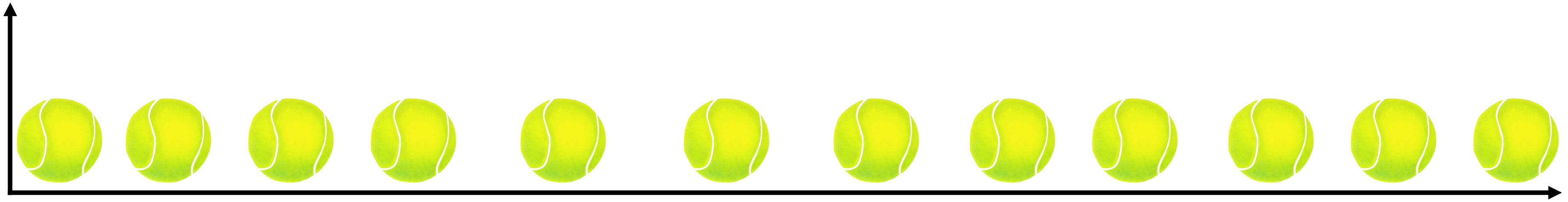
Initially we don't know the location of the robot so we have particles everywhere



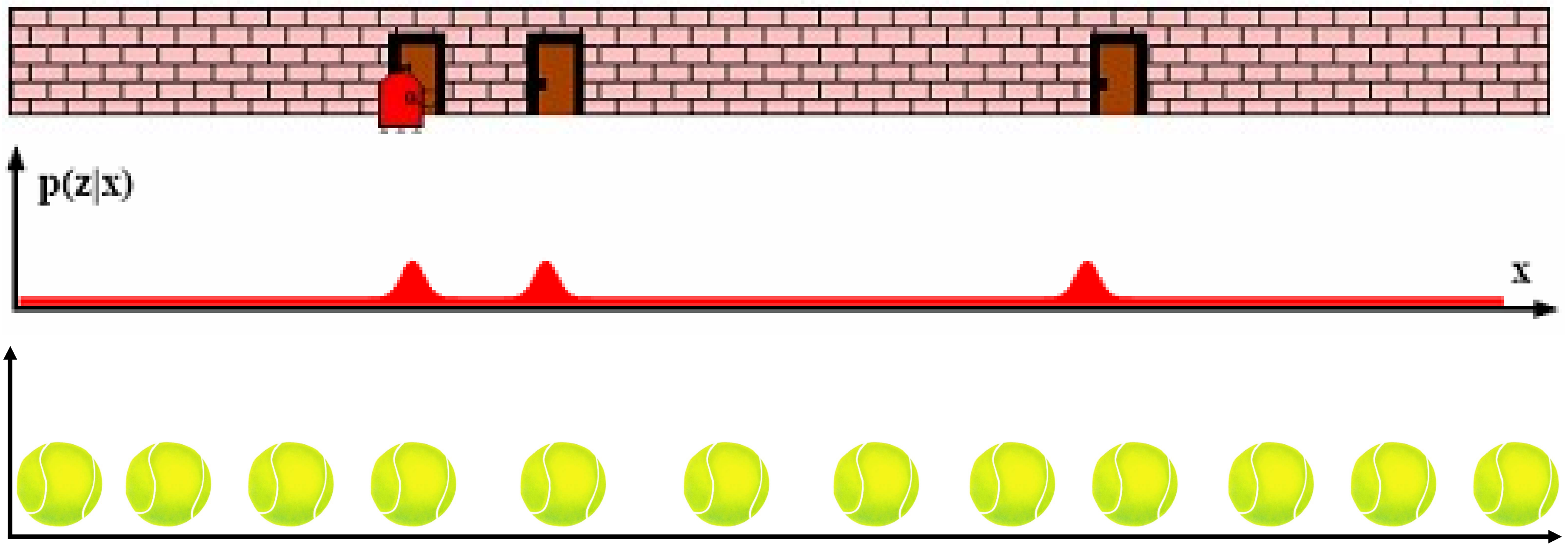


Next, the robot senses that it is near a door

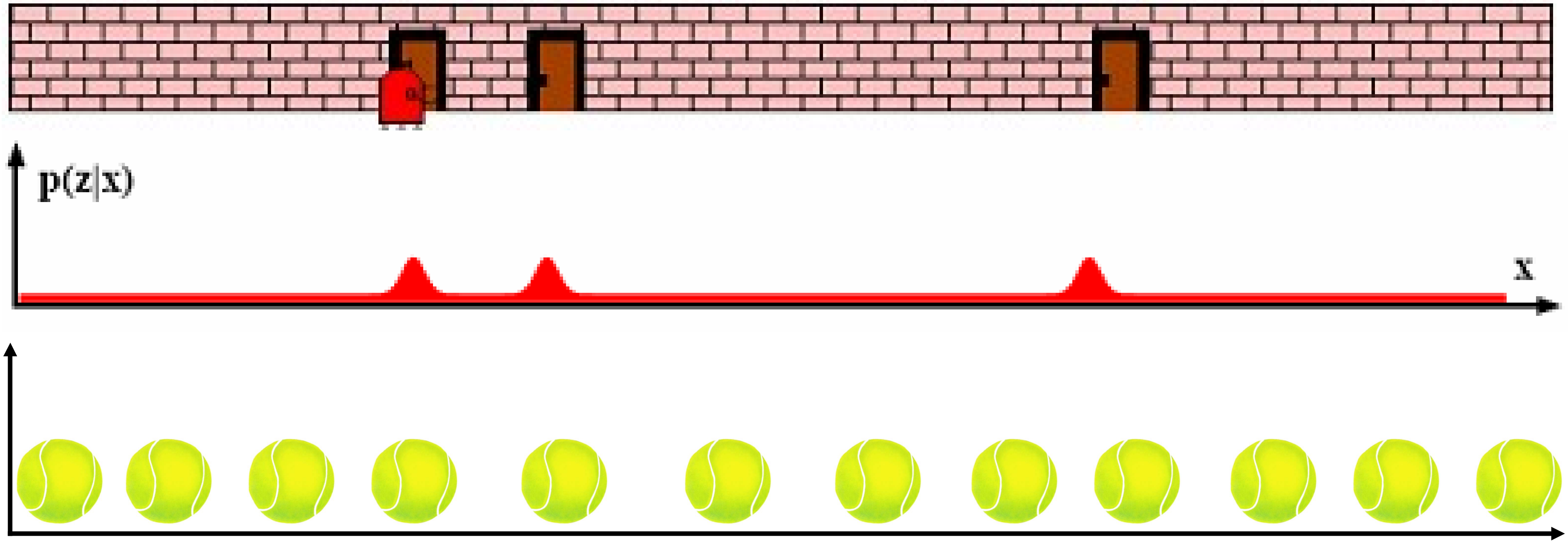




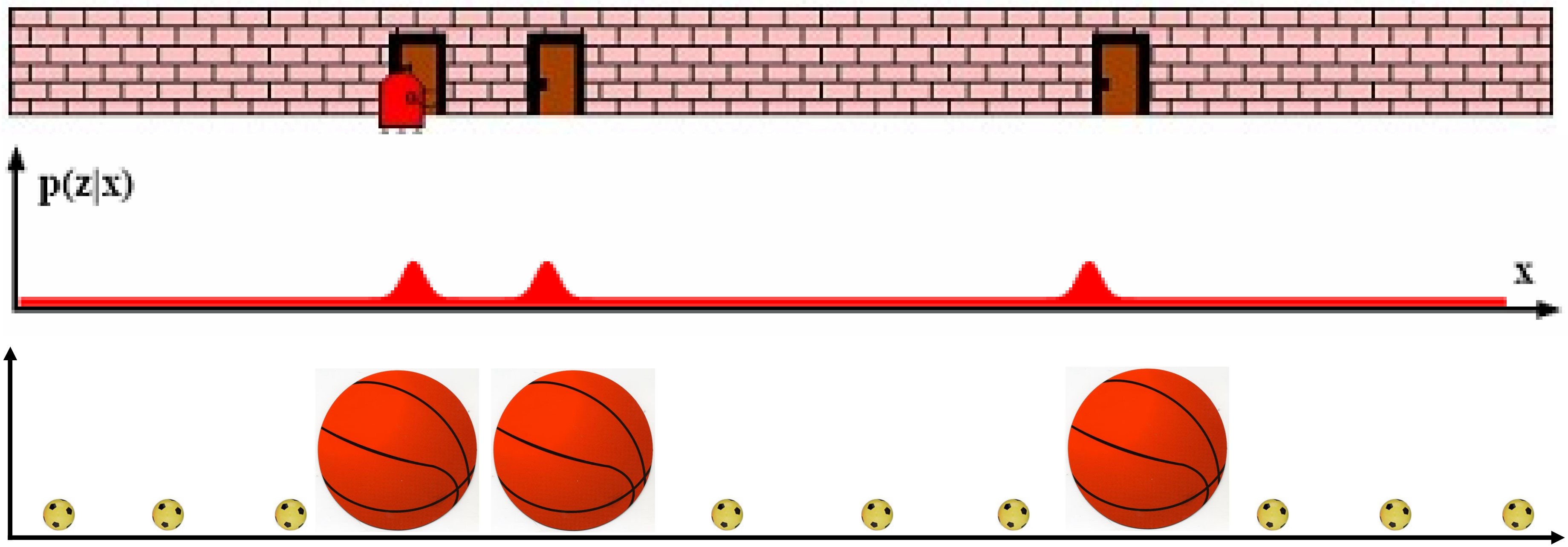
Since there are 3 identical doors the robot can be next to any one of them



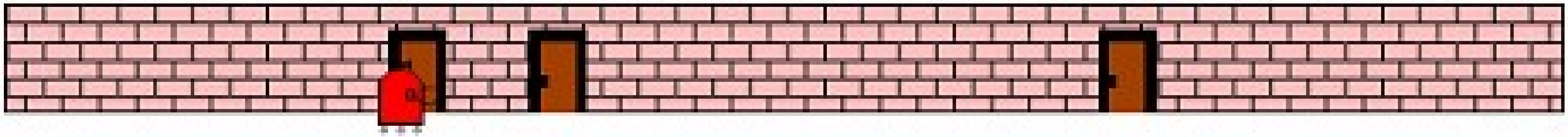
Therefore, we inflate balls (particles) that are next to doors and shrink all others

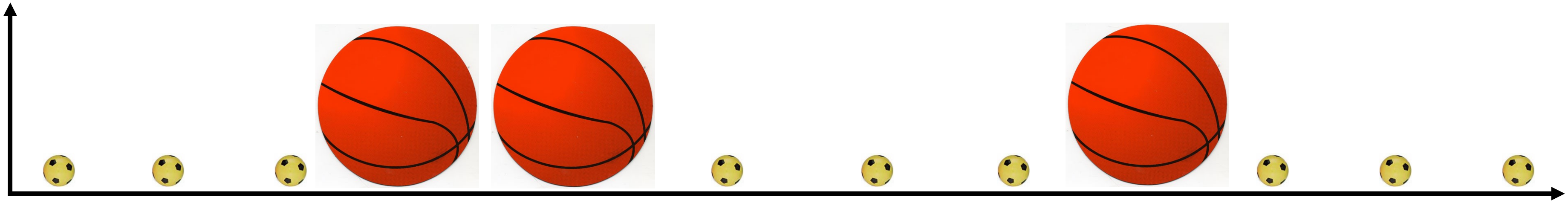


Therefore, we grow balls (particles) that are next to doors and shrink all others



Before we continue we have to make all balls to be of equal size. We need to resample.





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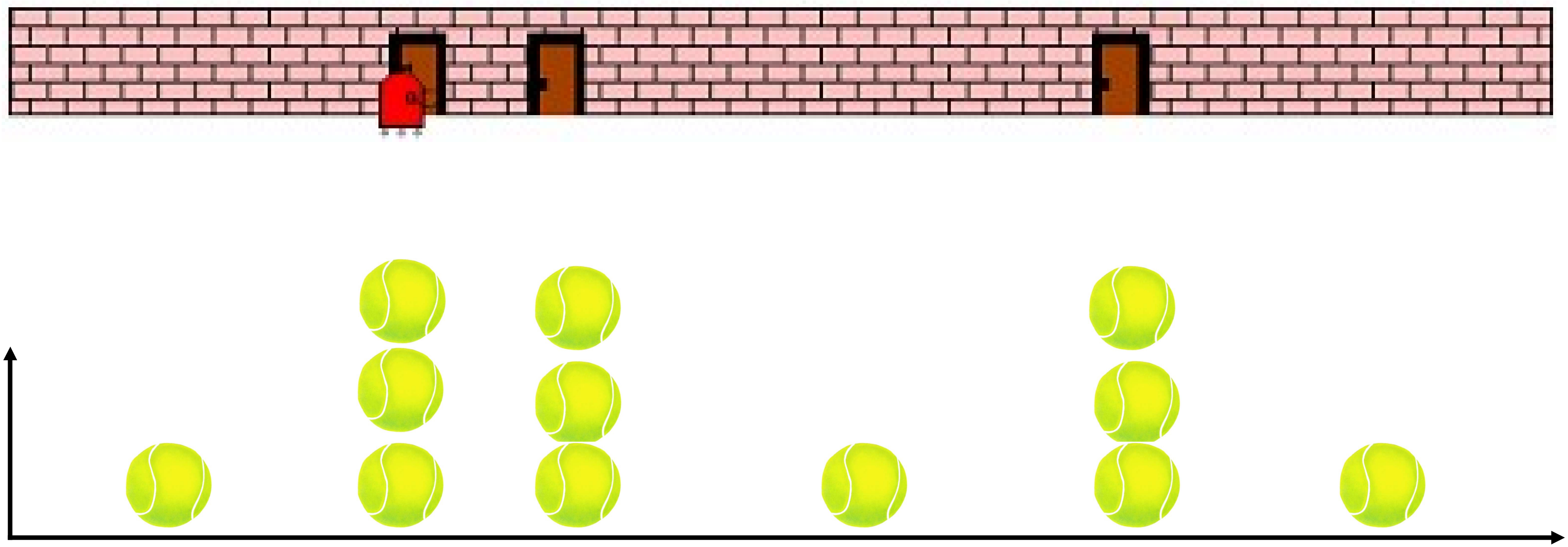
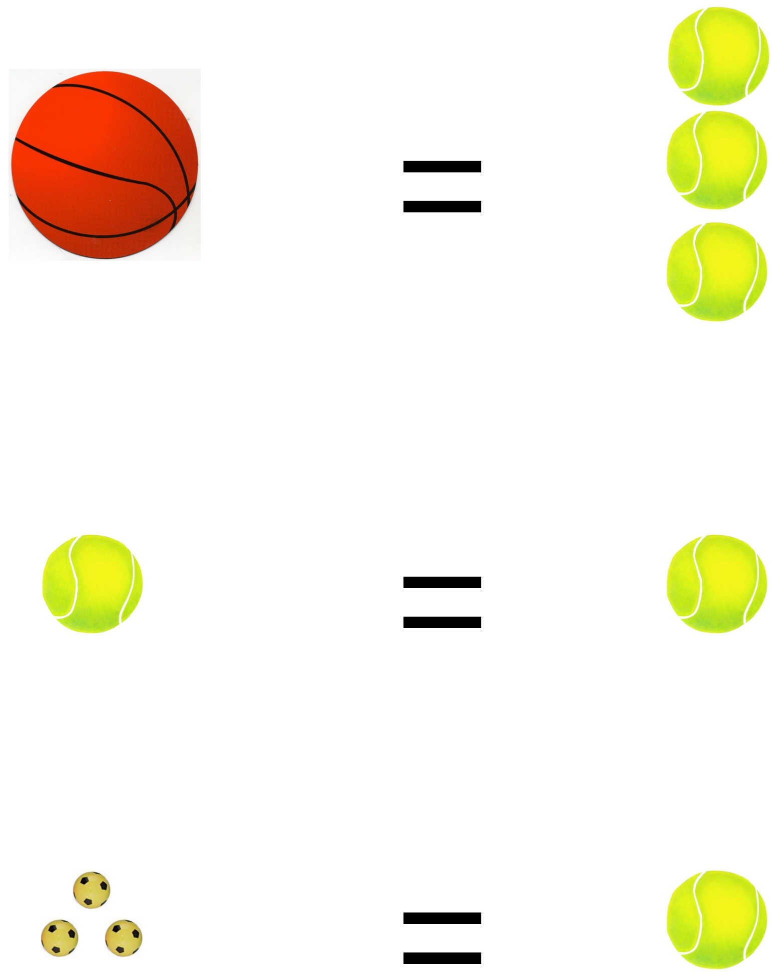


Resampling Rules



Resampling

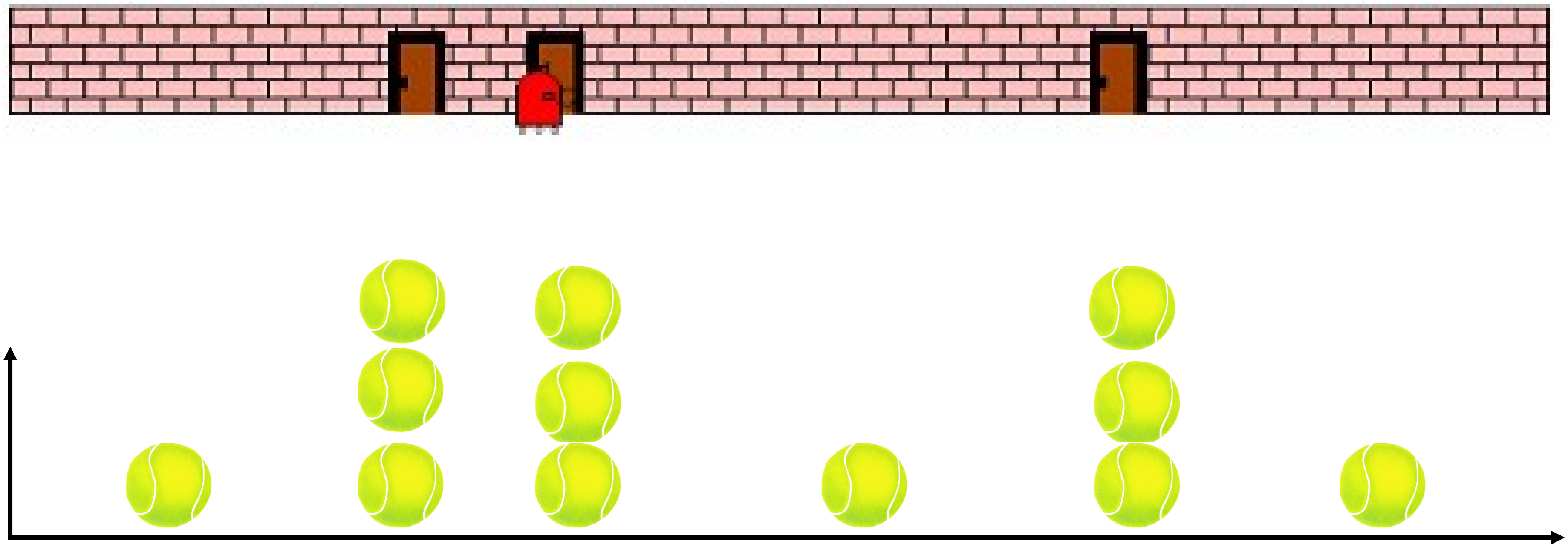
- **Given**: Set S of weighted samples.

- **Wanted** : Random sample, where the probability of drawing x_i is given by w_i.

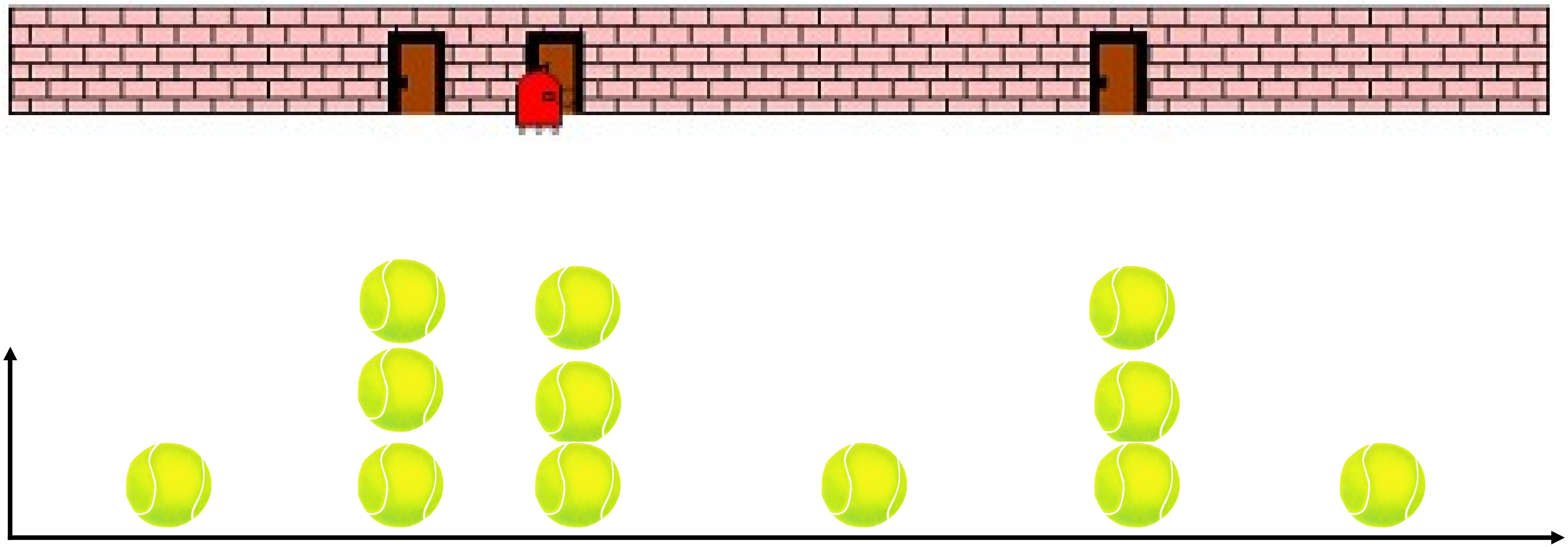
- Typically done n times with replacement to generate new sample set S'.

[From Thrun's book "Probabilistic Robotics"]

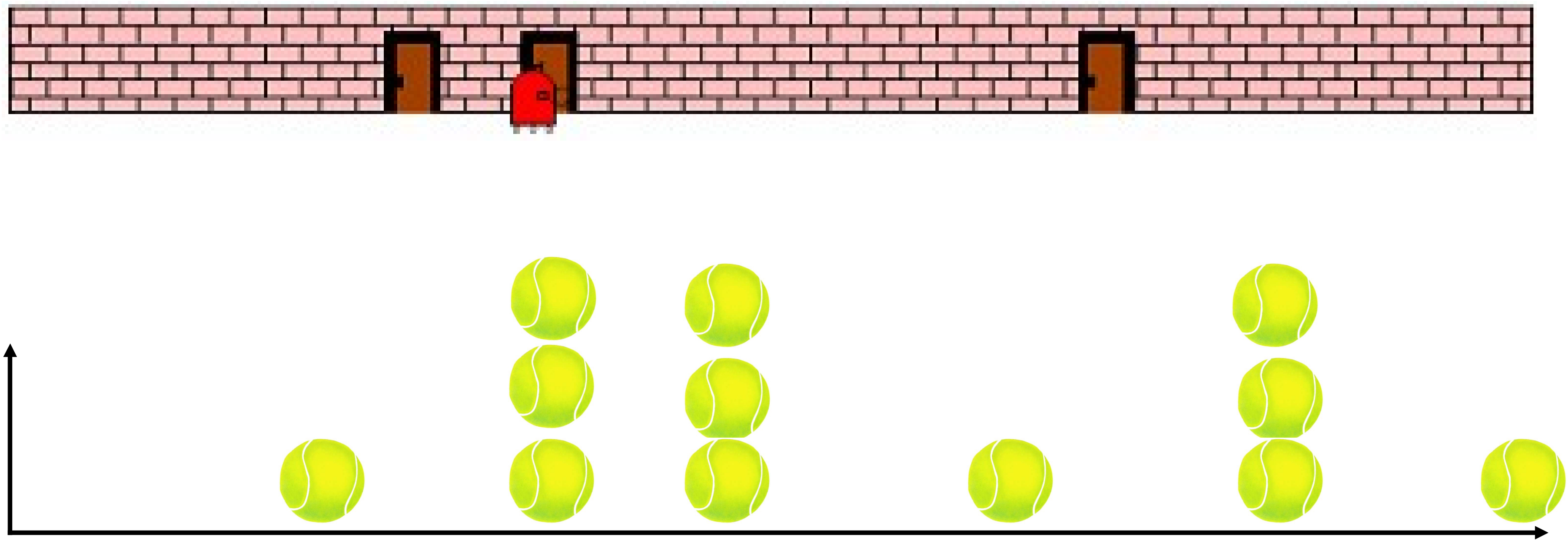
Next, The robot moves to the right



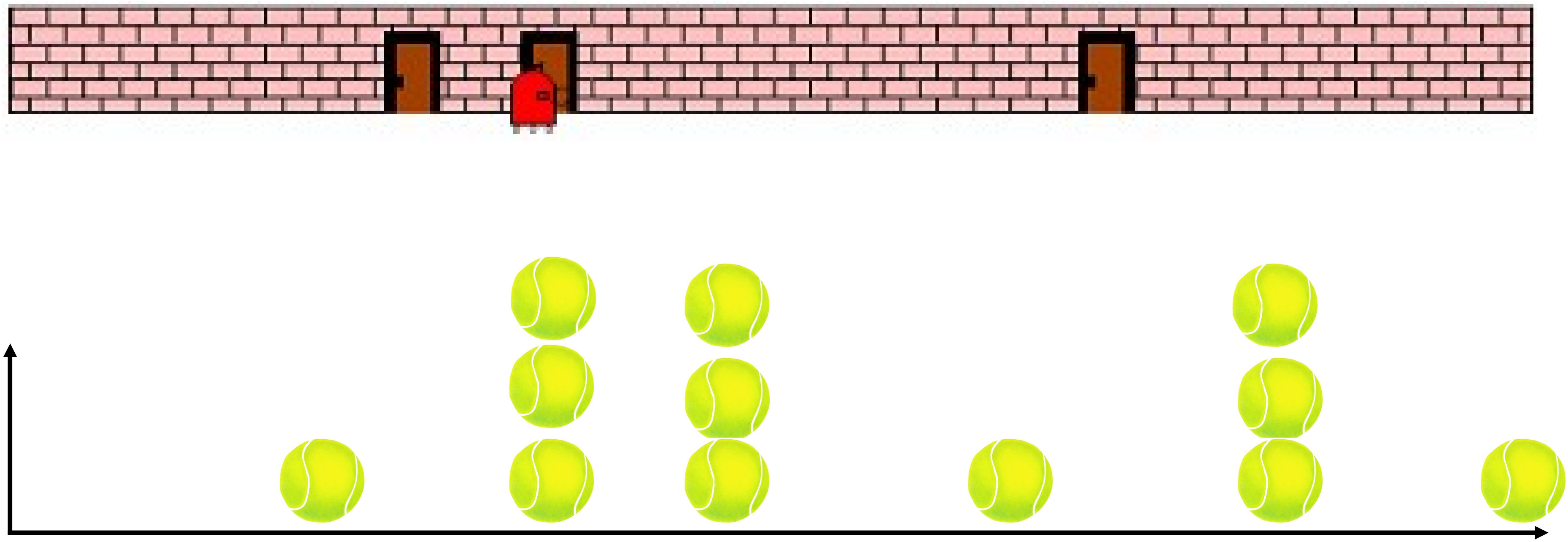
… thus, we have to shift all balls (particles) to the right



… thus, we have to shift all balls (particles) to the right



… and add some position noise



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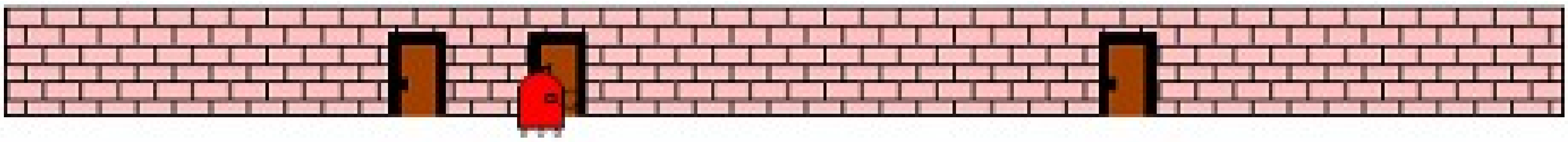
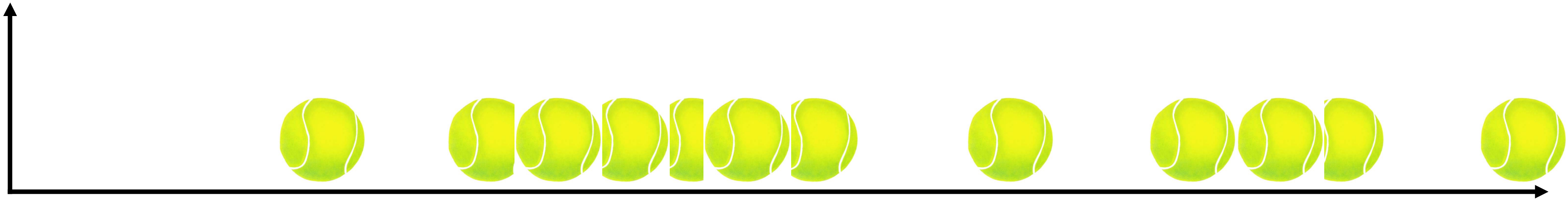
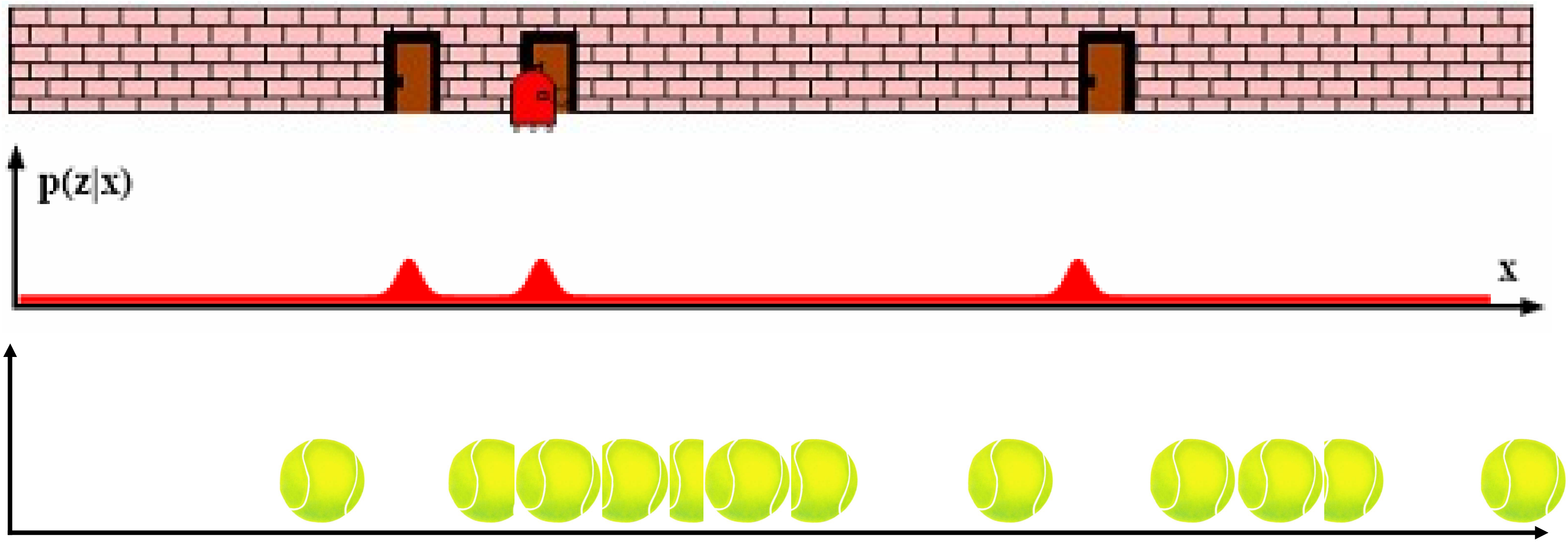
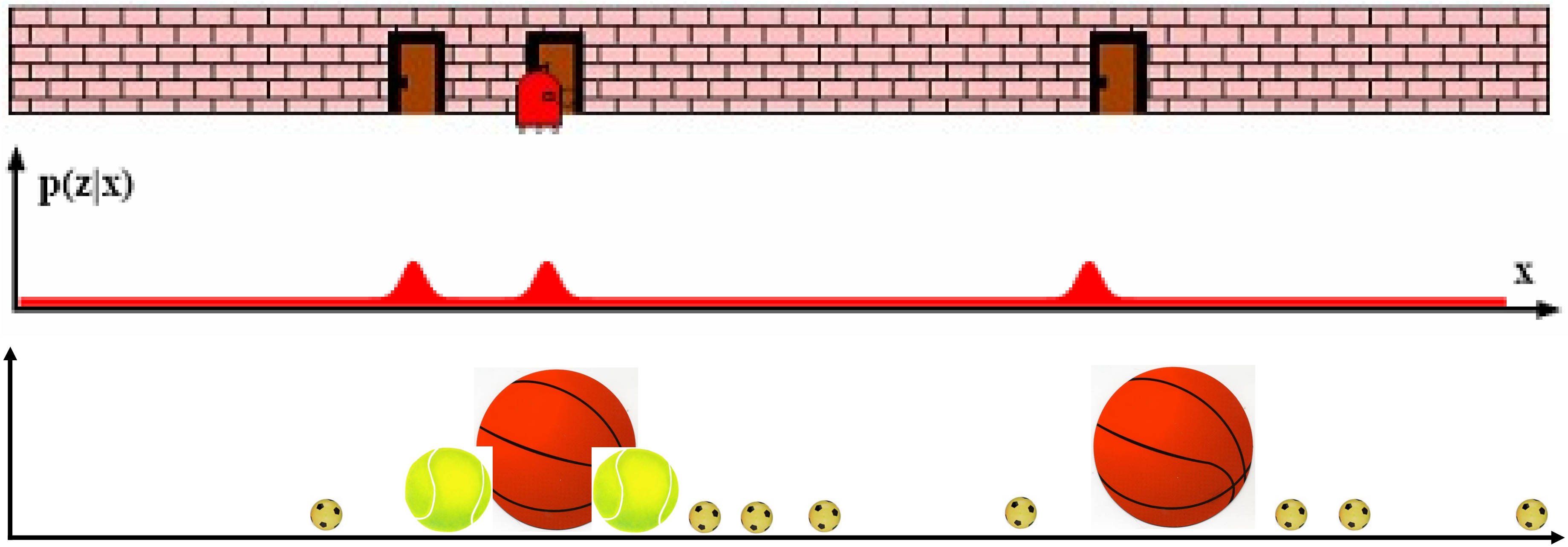




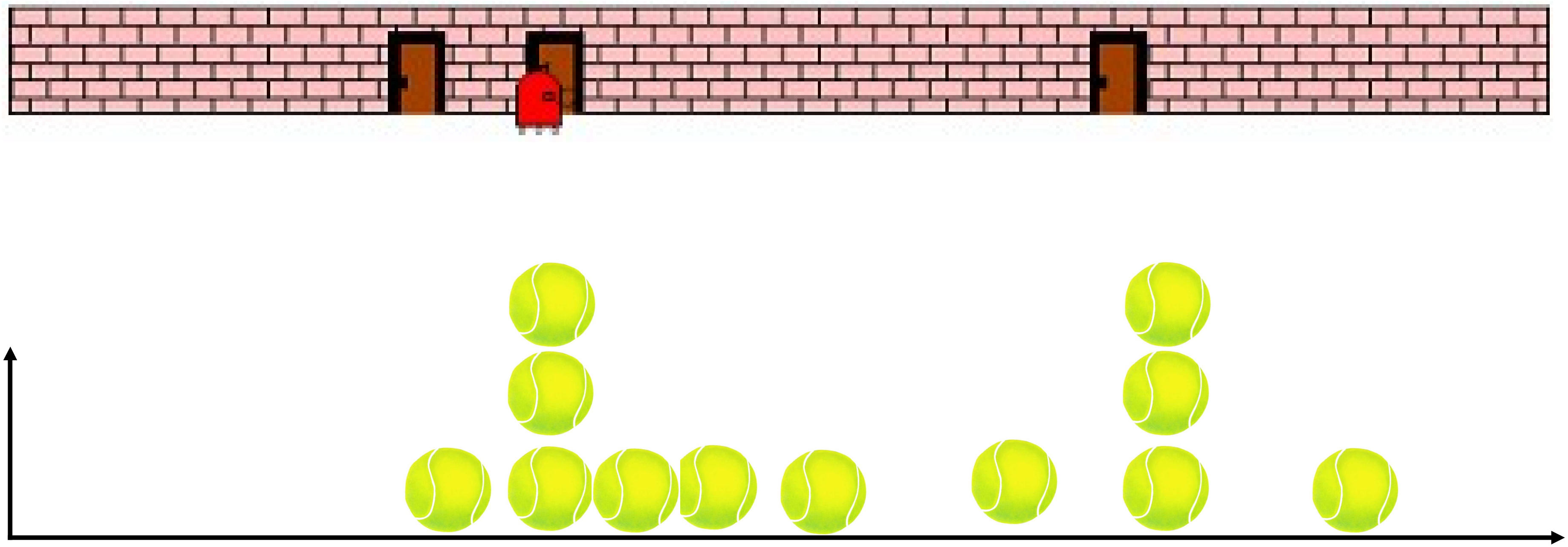
Next, the robot senses that it is next to one of the three doors



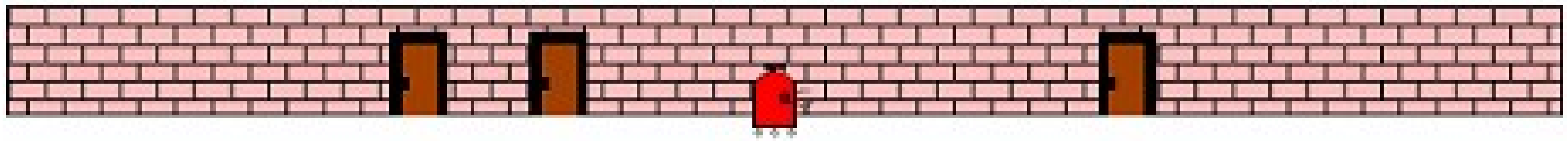
Next, the robot senses that it is next to one of the three doors

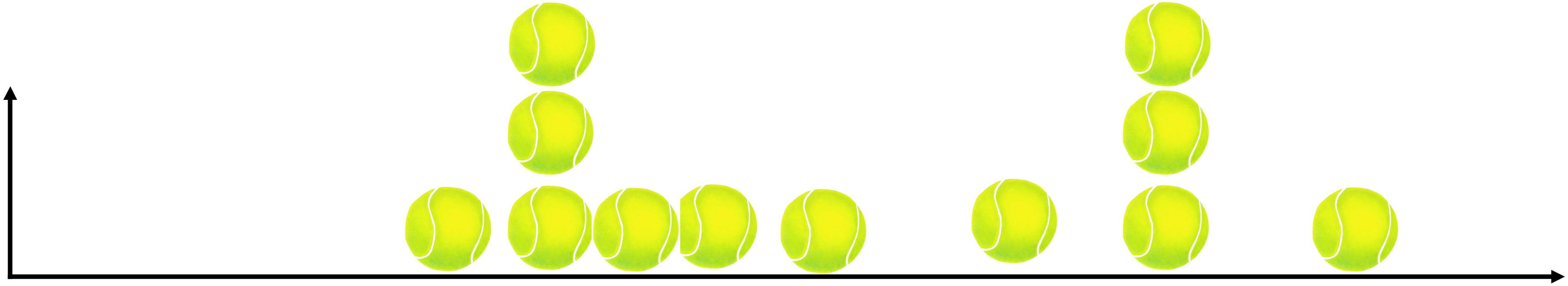


Now we have to resample again

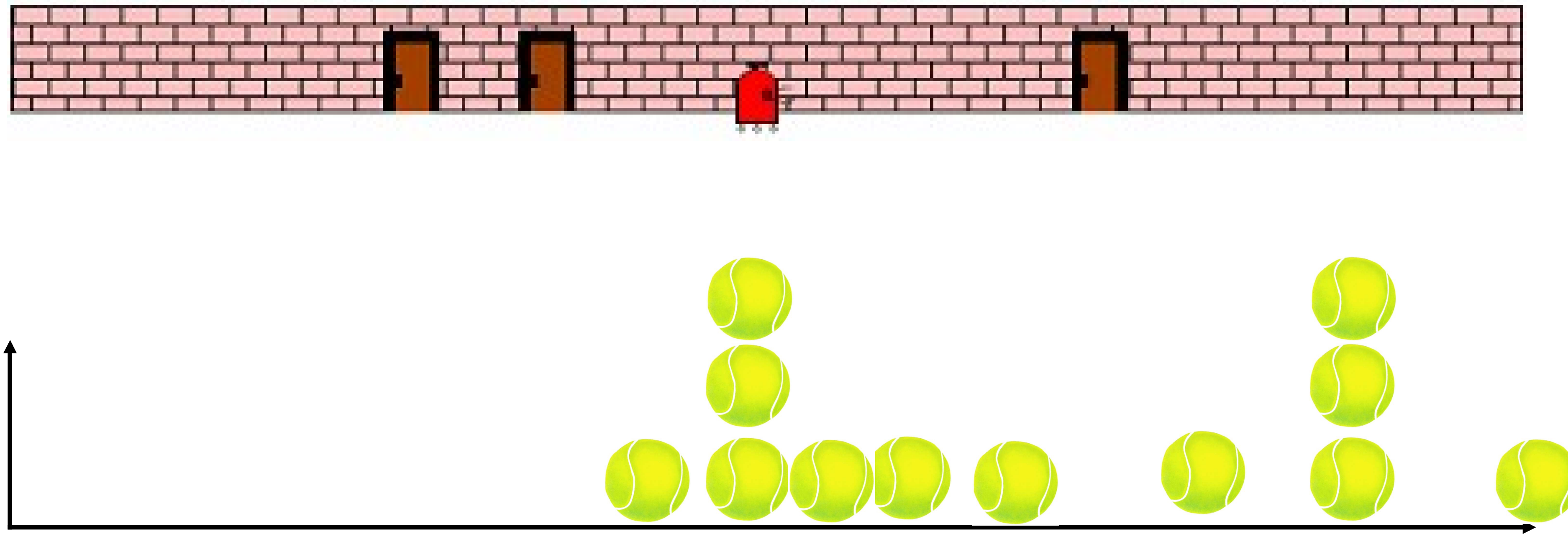


The robot moves again

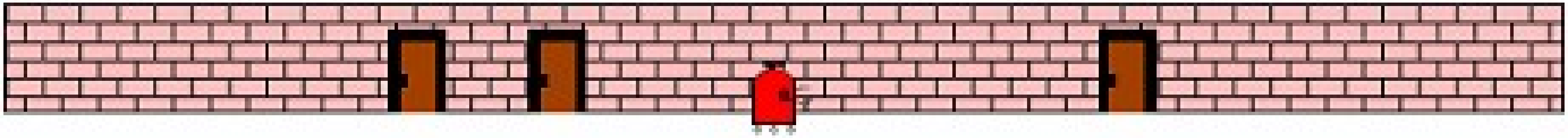


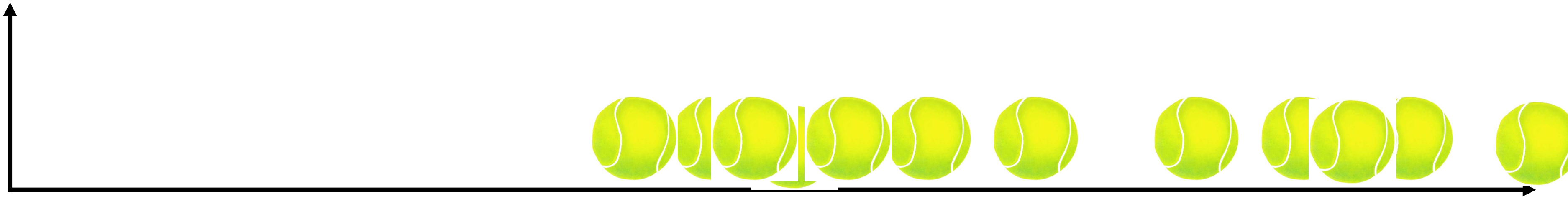


… so we must move all balls (particles) to the right again



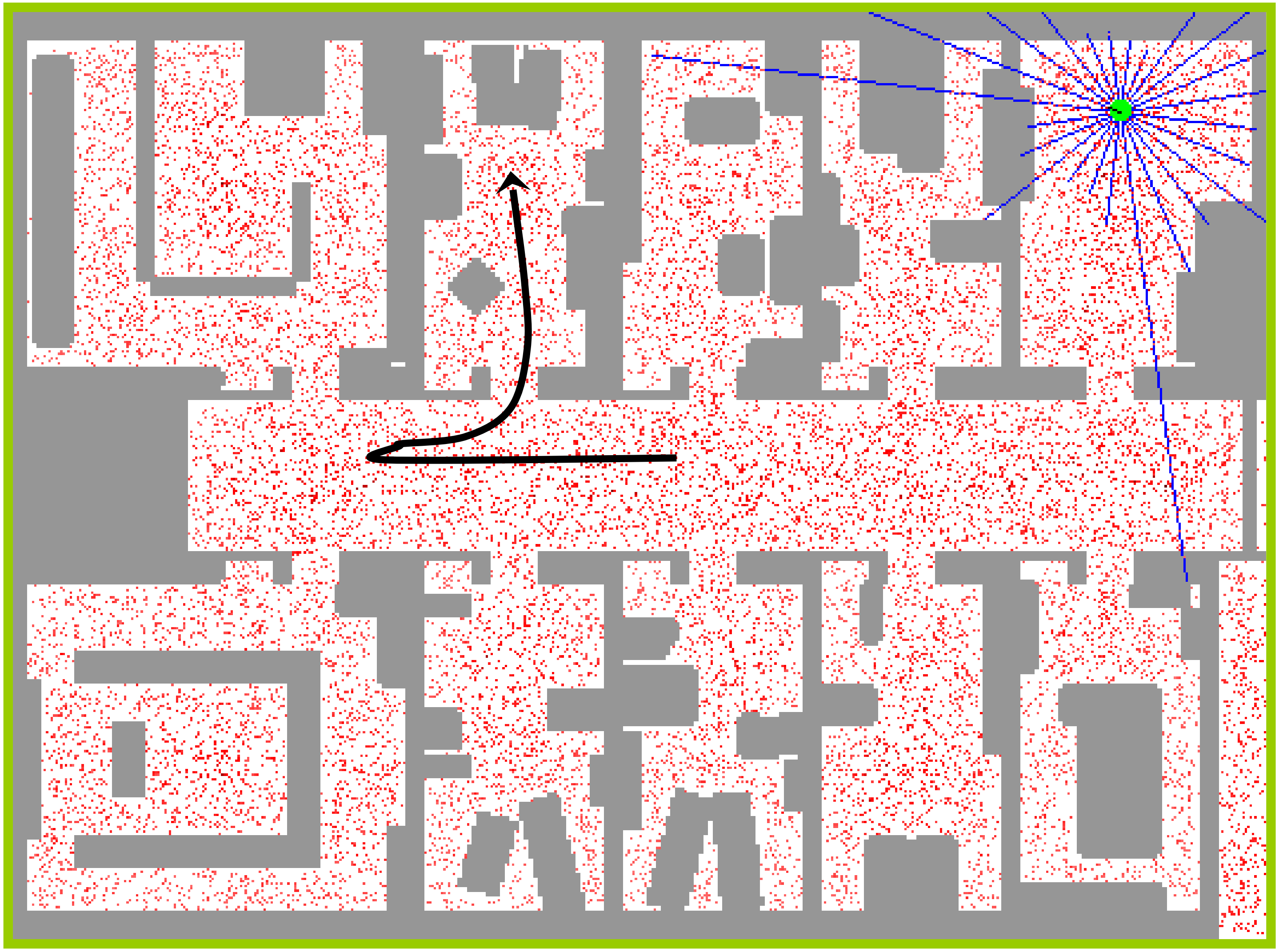
… and add some position noise

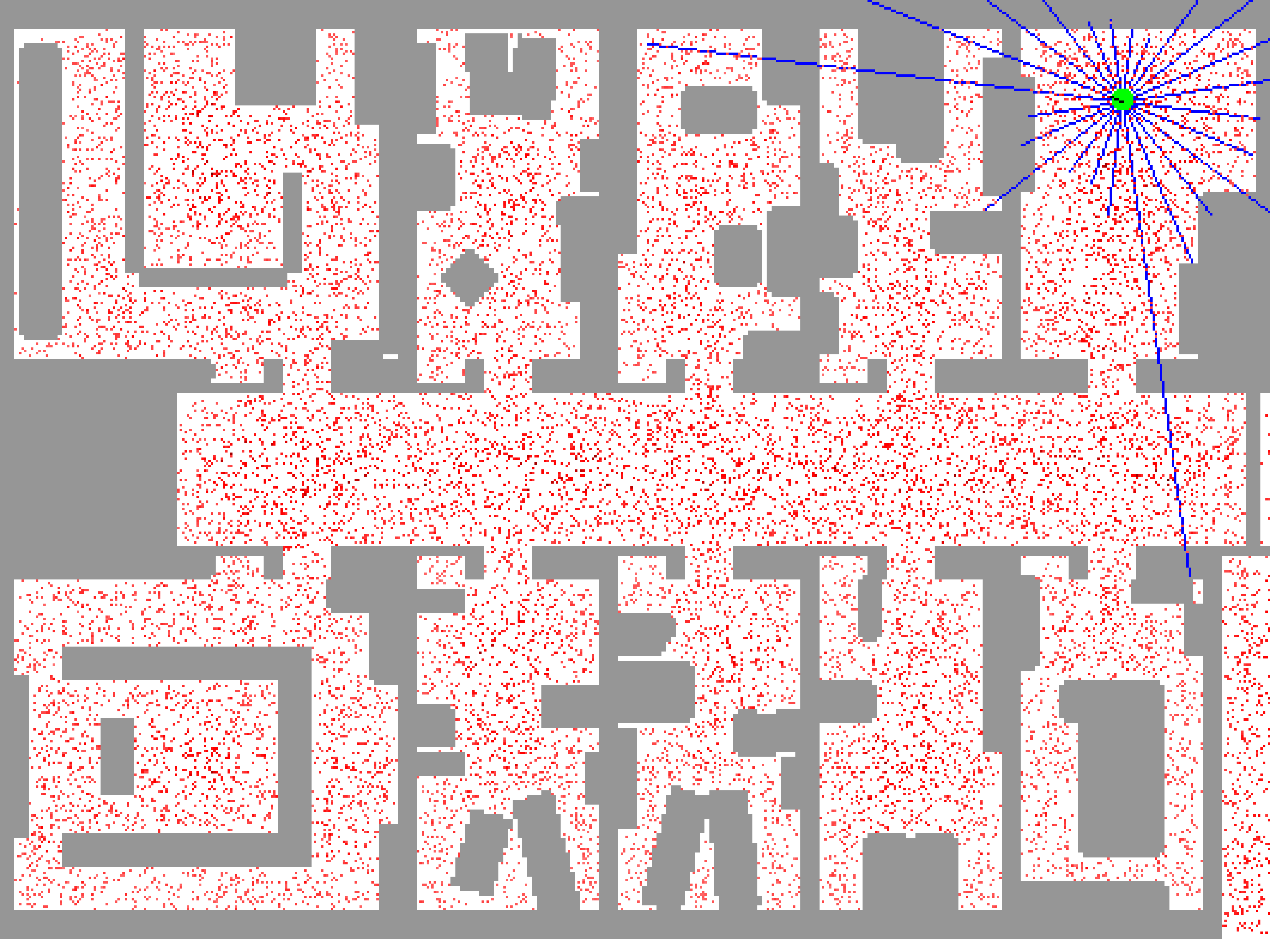




And so on …

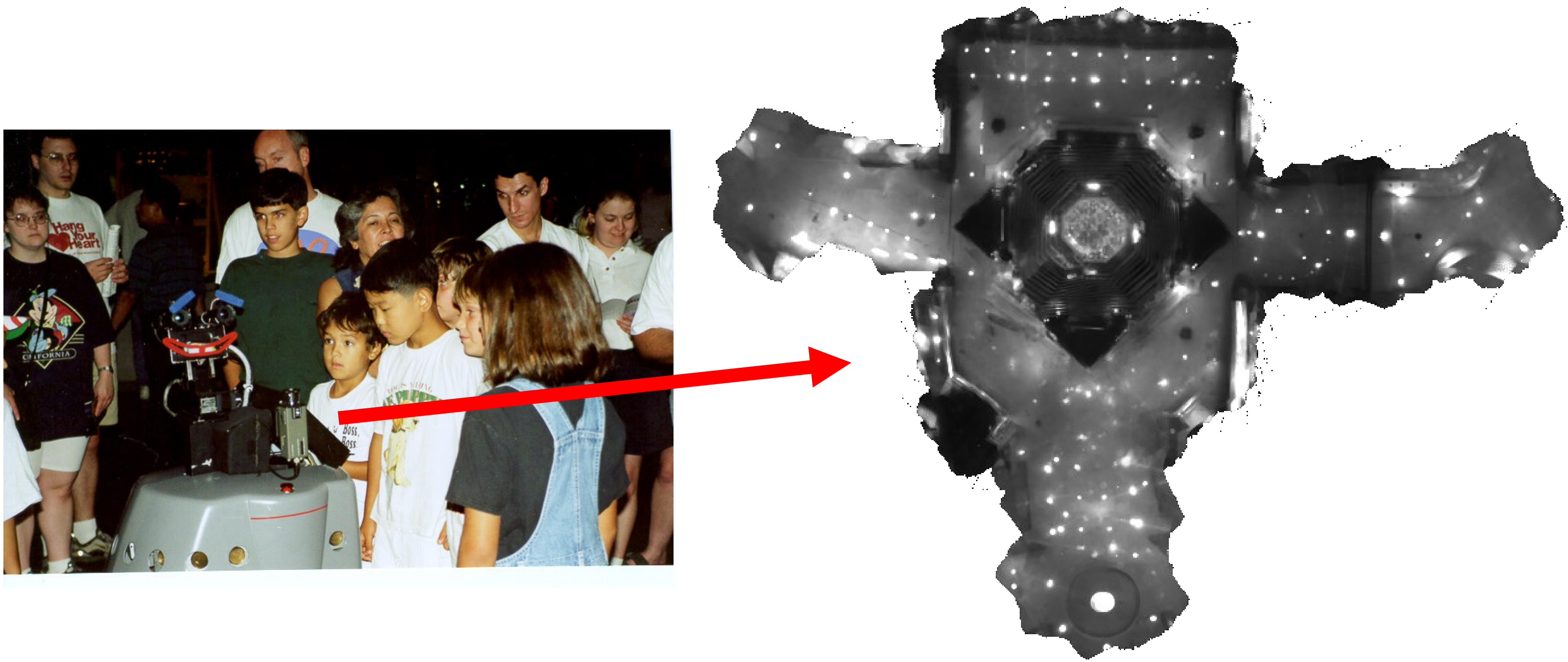
Localization using Sonar



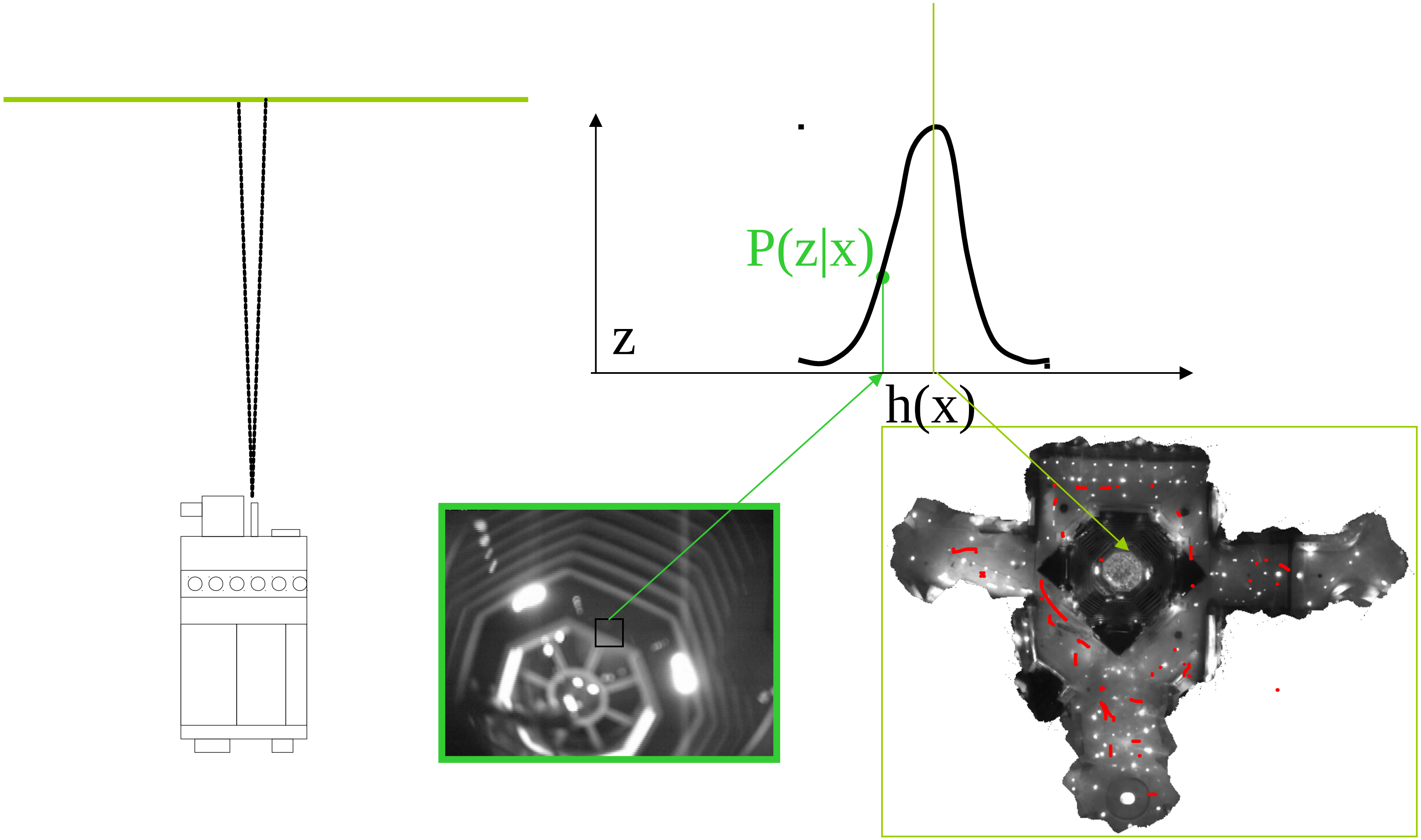


What does this look like on a real robot?

Using Ceiling Maps for Localization

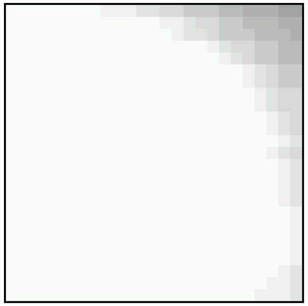


Vision-based Localization

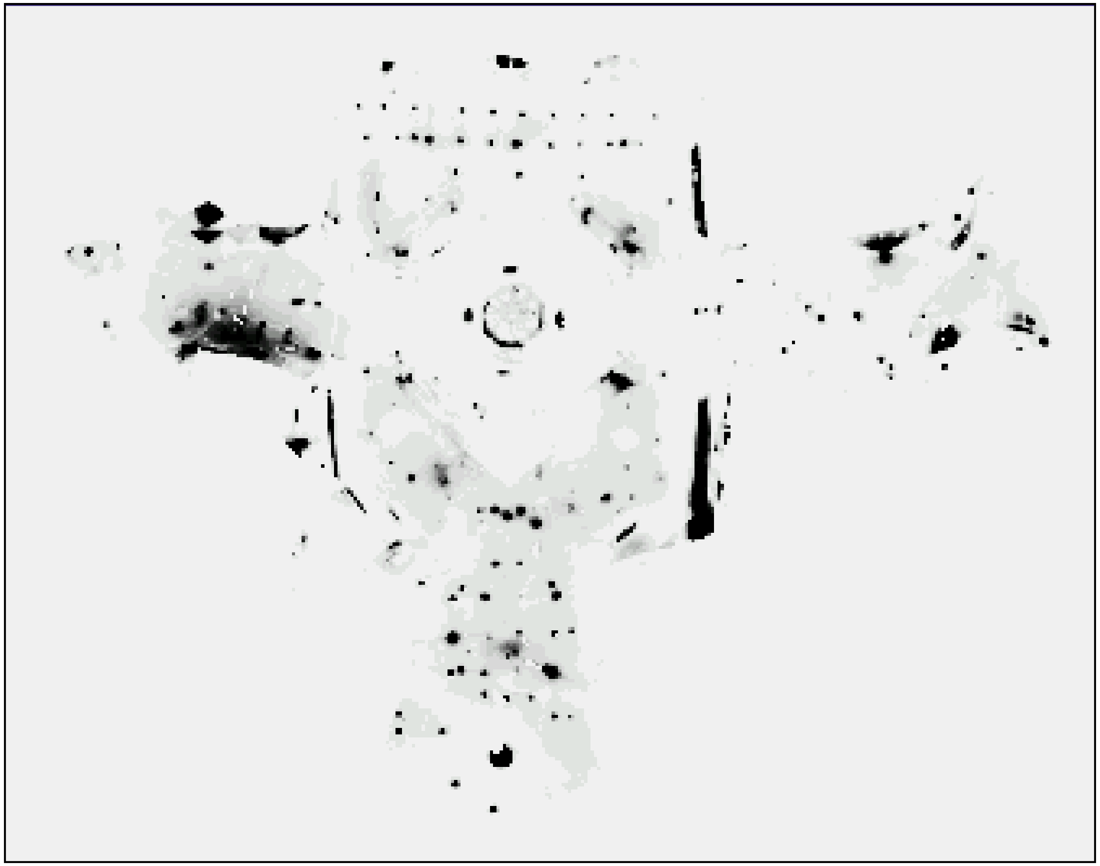


Under a Light

Measurement z:

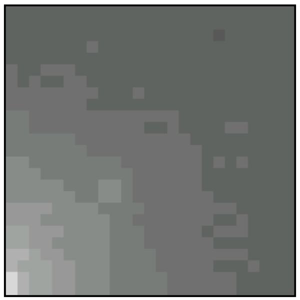


P(z|x):

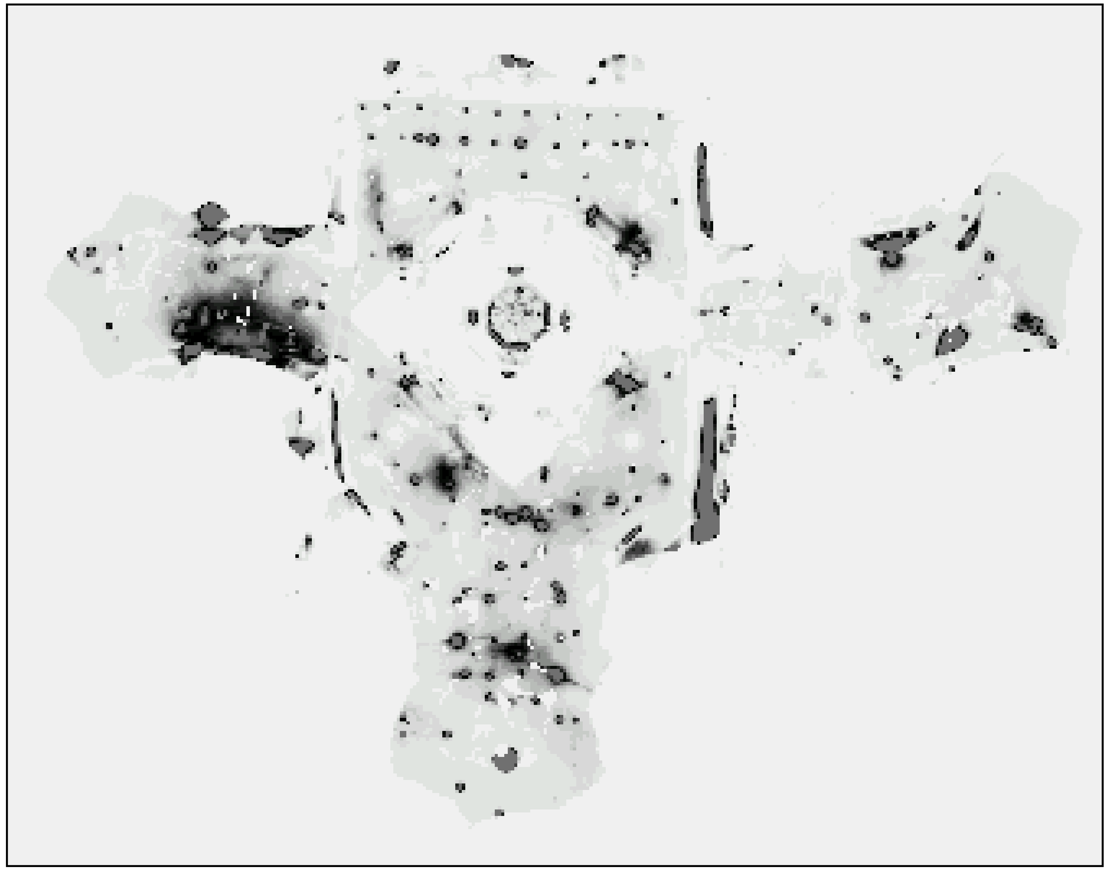


Next to a Light

Measurement z:



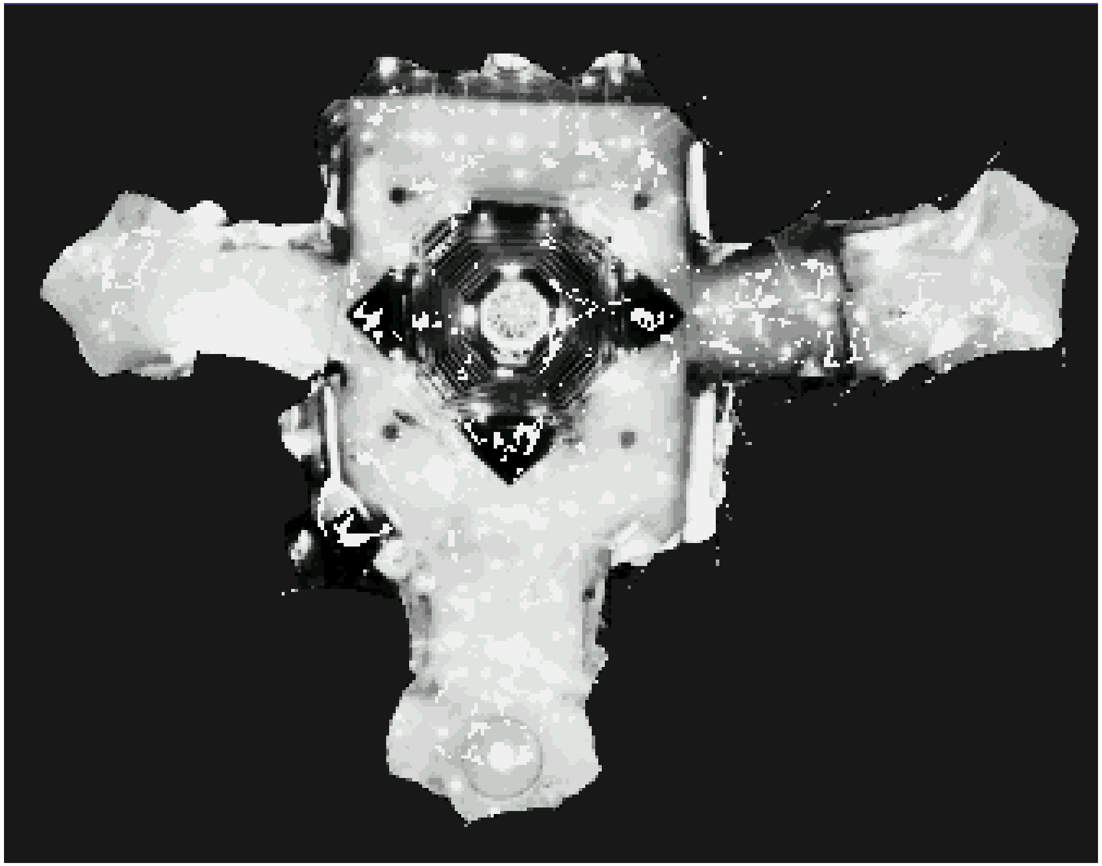
P(z|x):



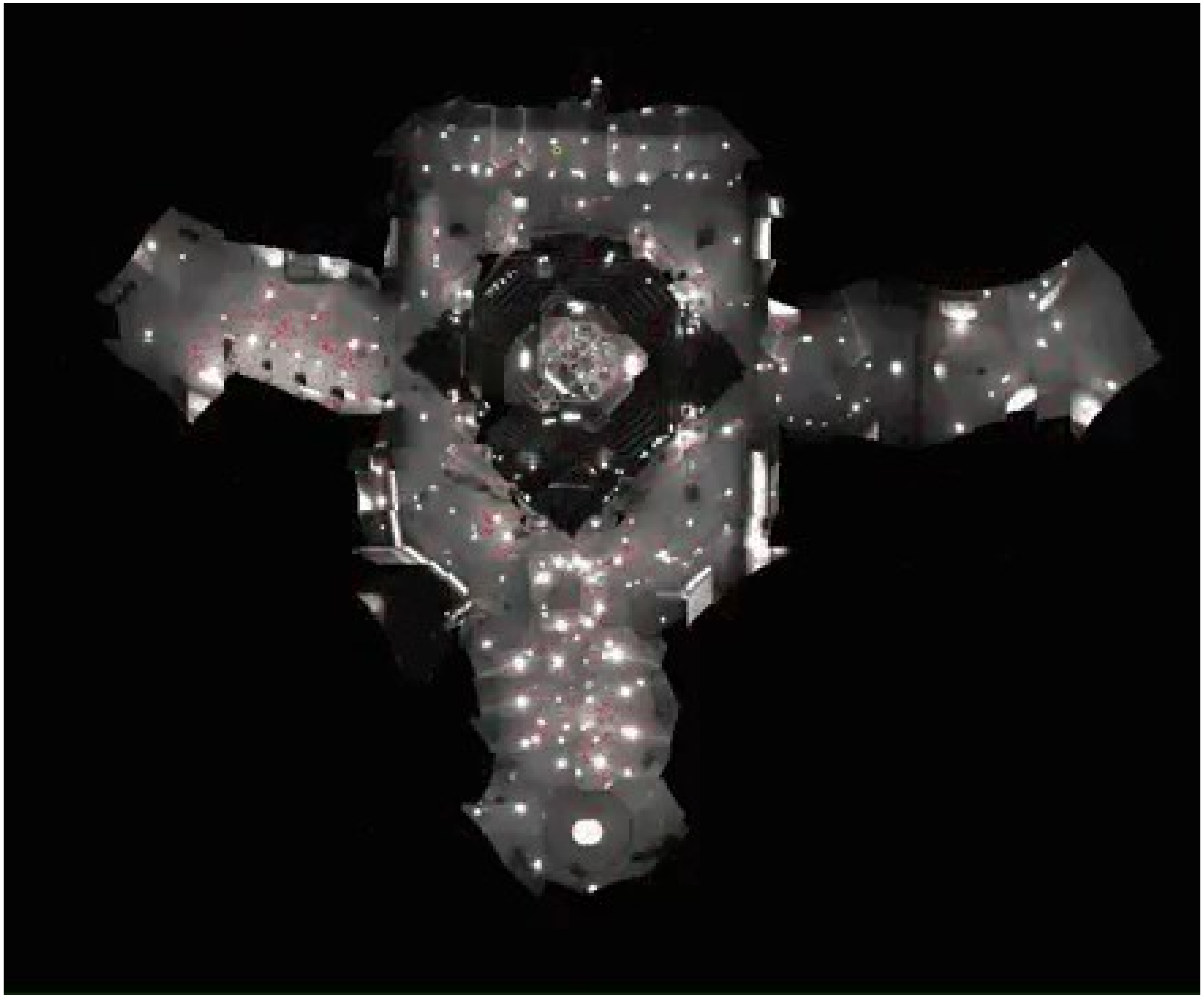
Elsewhere

Measurement z:

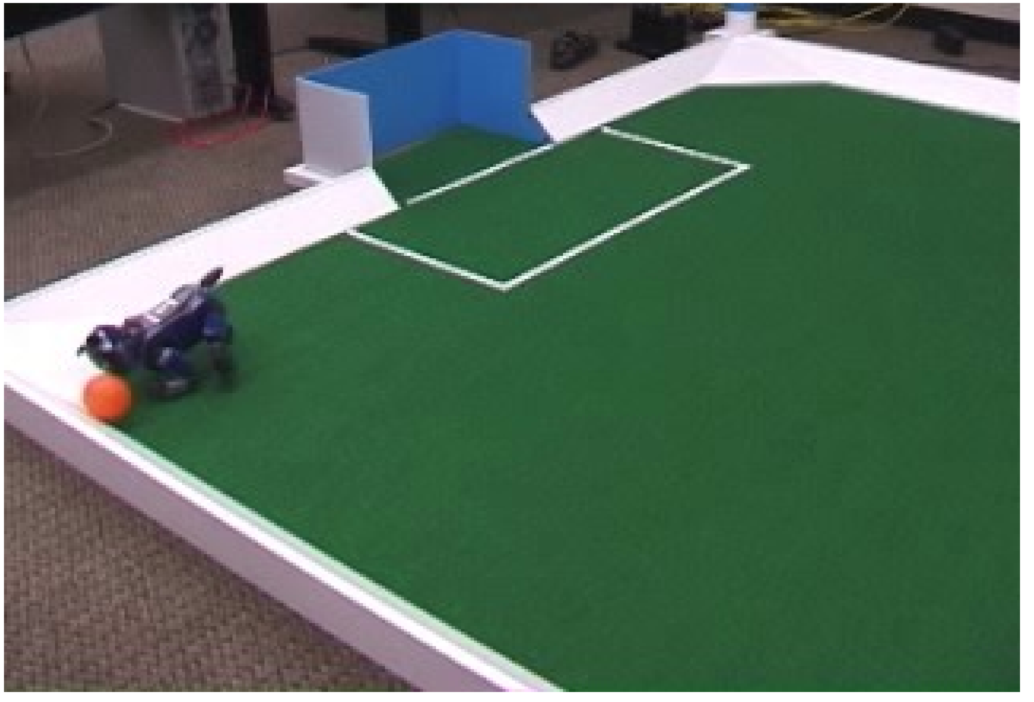
P(z|x):



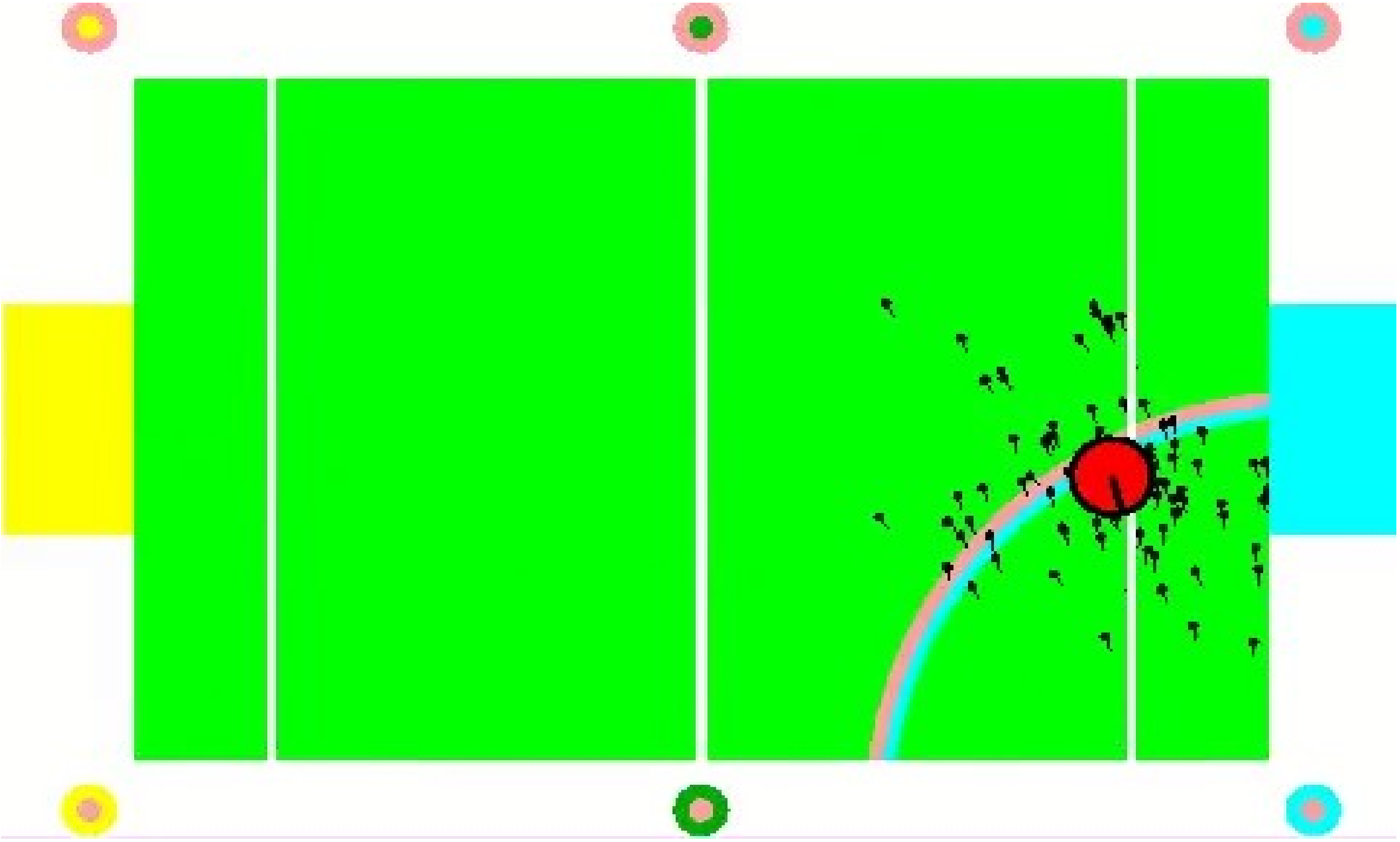
Global Localization Using Vision



Example in RoboCup



Example in RoboCup



How does all of this work in ROS?

- ROS package for “Adaptive Monte-Carlo Localization” with 2D laser readings: ***amcl***
- ROS package for building 2D maps: ***gmapping***

Overview of Homework 5

- Due March 22nd

THE END