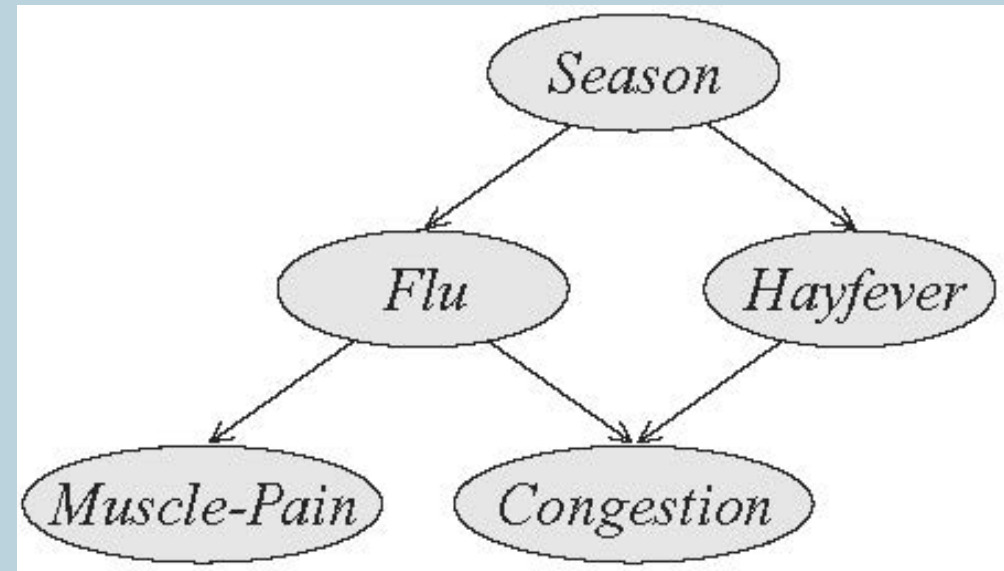
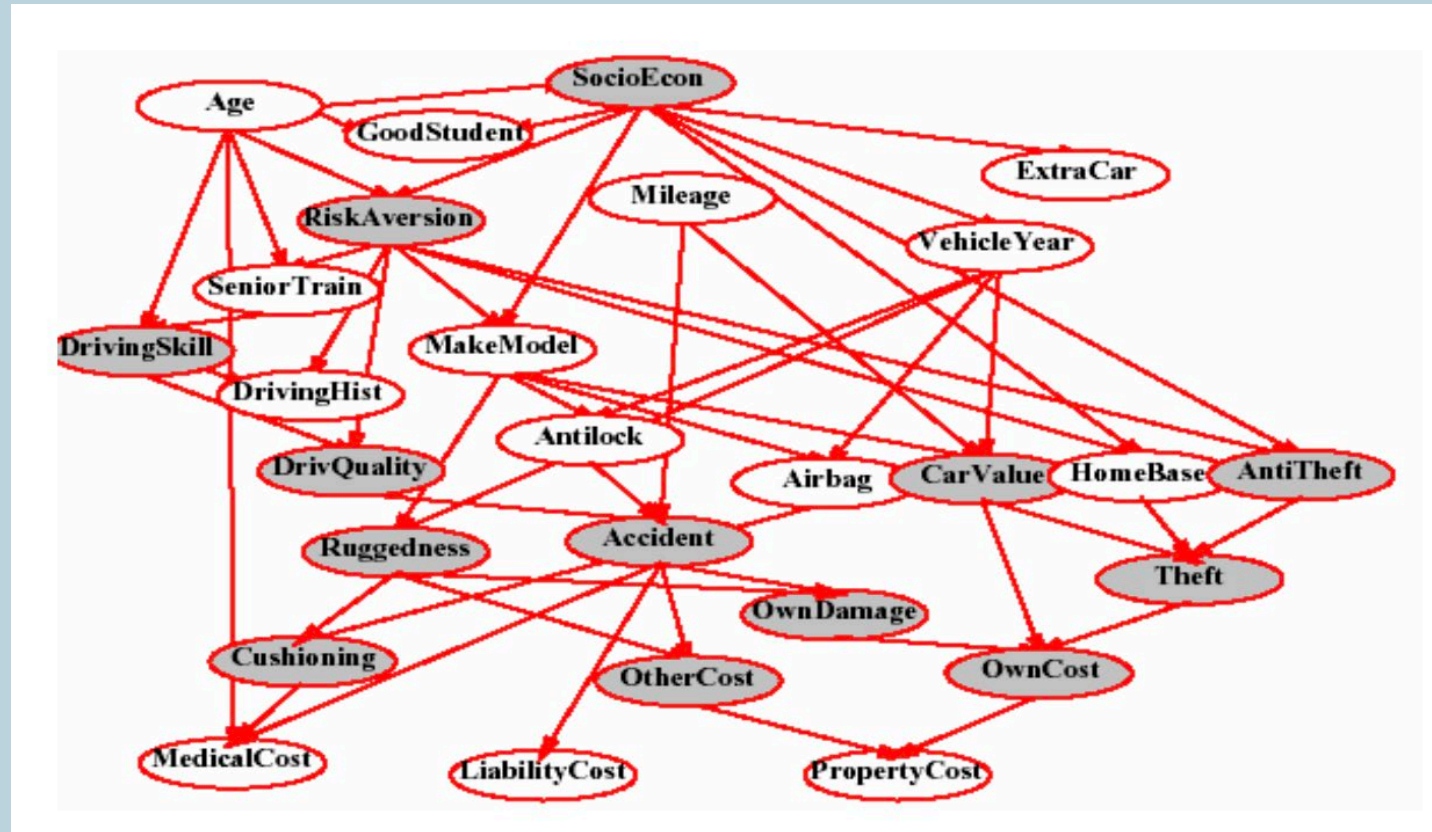


Probabilistic Graphical Models

- So far, simple dependency structures
- In reality, there could be very complex interdependencies!
- Probabilistic Graphical Model
 - Nodes: Random variables
 - Edges: Dependency relationships
- $P(\text{Flu} \mid \text{Season}, \text{Congestion})$



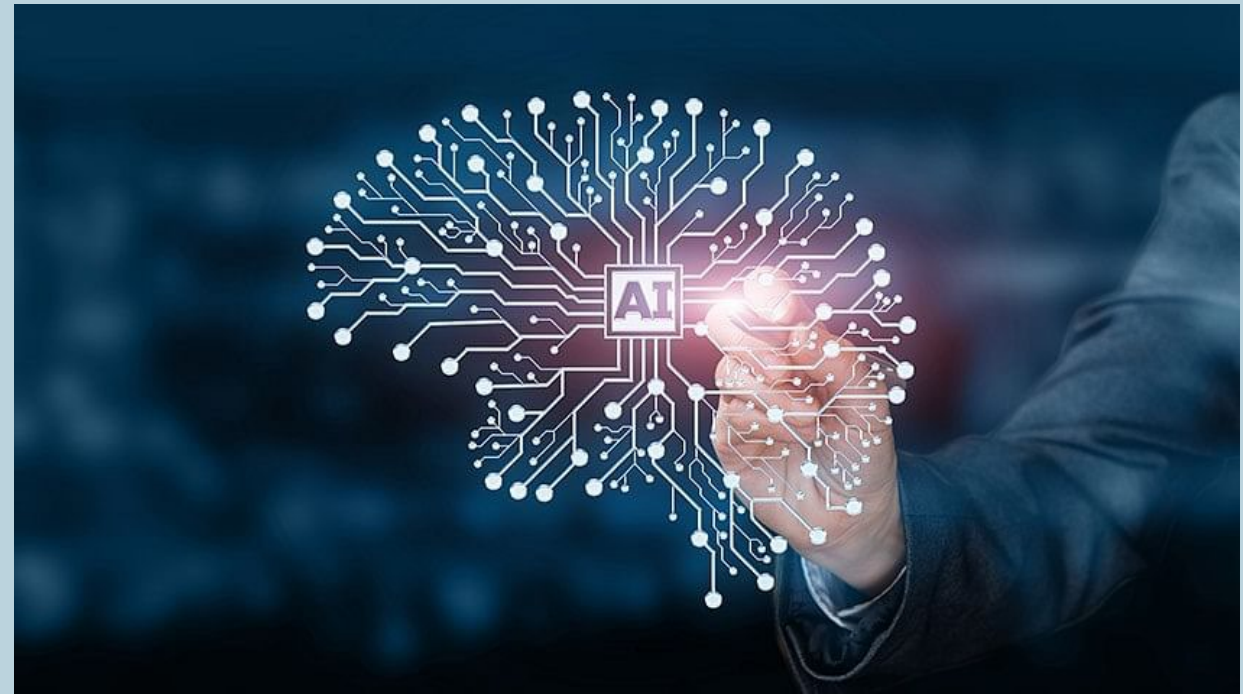
Probabilistic Graphical Models



- $P(\text{LiabilityCost})$?

Probabilistic AI

- Probabilistic modeling is at the core of many AI techniques
 - Bayesian linear regression
 - Gaussian processes
 - Variational inference
 - Active Learning
 - Reinforcement learning
 - Imitation learning
 - Monte Carlo Tree Search
 - Planning
 - ...

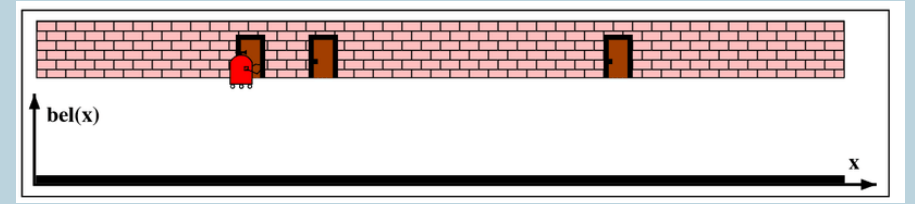


Probabilistic Robotics

- Robots should make decisions based on the uncertainty of the information they have
- Probabilistic modeling is part of most areas in robotics
 - Perception
 - Localization
 - State estimation
 - Robust reasoning
 - Control
 - ...

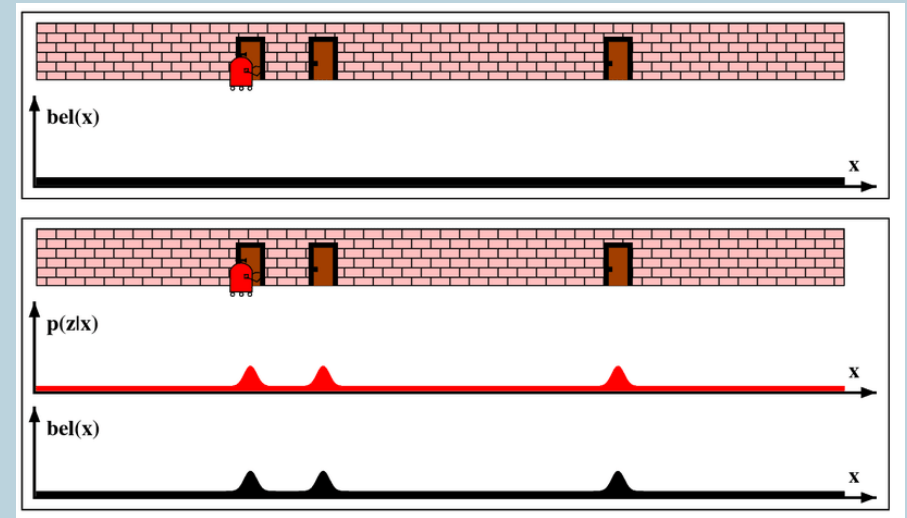
Probabilistic Robot Localization

- A mobile robot in a corridor
- $X \rightarrow$ Location of the robot along the corridor
- The robot knows the form of the corridor (length, doors, distance between doors) but doesn't know where it is
- $\text{bel}(x) \rightarrow$ Where the robot *believes* it is
- The robot has a sensor that tells the robot when it is in front of a door
- Initially, the robot doesn't know where it is (all points along the corridor are equally probable)



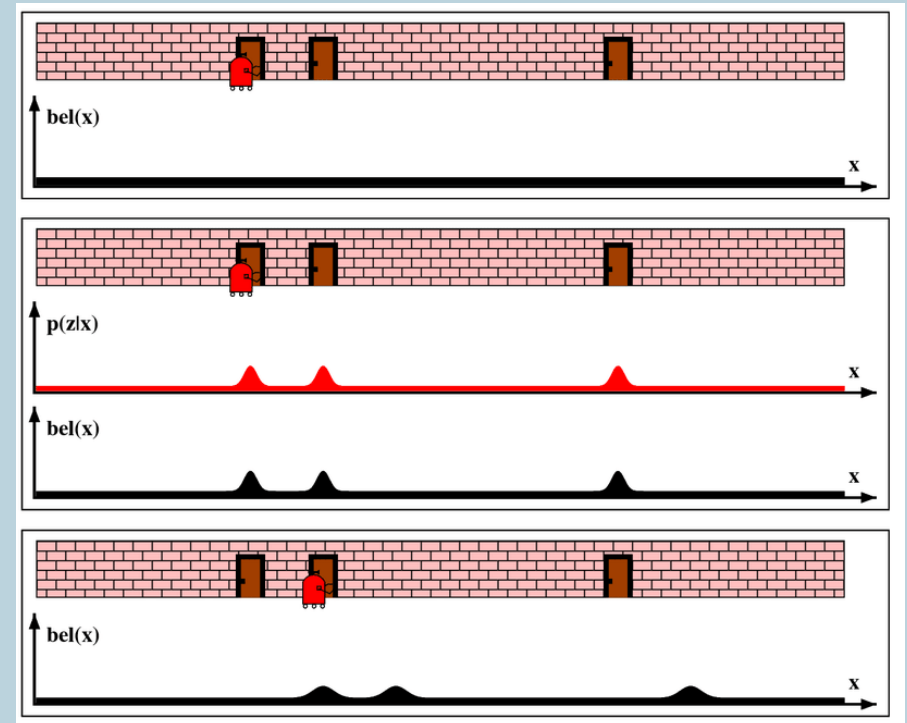
Probabilistic Robot Localization

- The robot receives a sensor reading: “you are in front of a door”!
- $p(z|x) \rightarrow$ Probability of reading “in front of a door” conditioned on different locations along the corridor
- Three locations are the most probable, the other are not so much



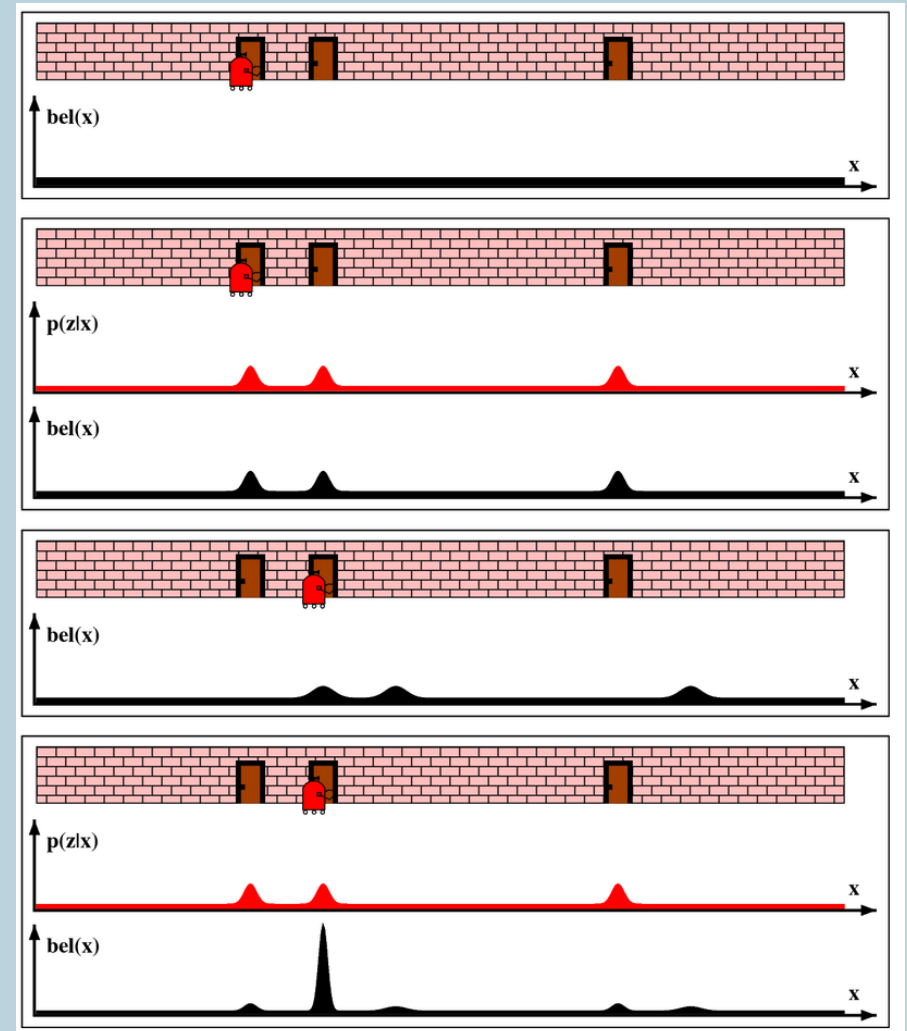
Probabilistic Robot Localization

- The robot moves a bit
 - The distance that separates the first and the second doors
- We take the believe and “move it” forward



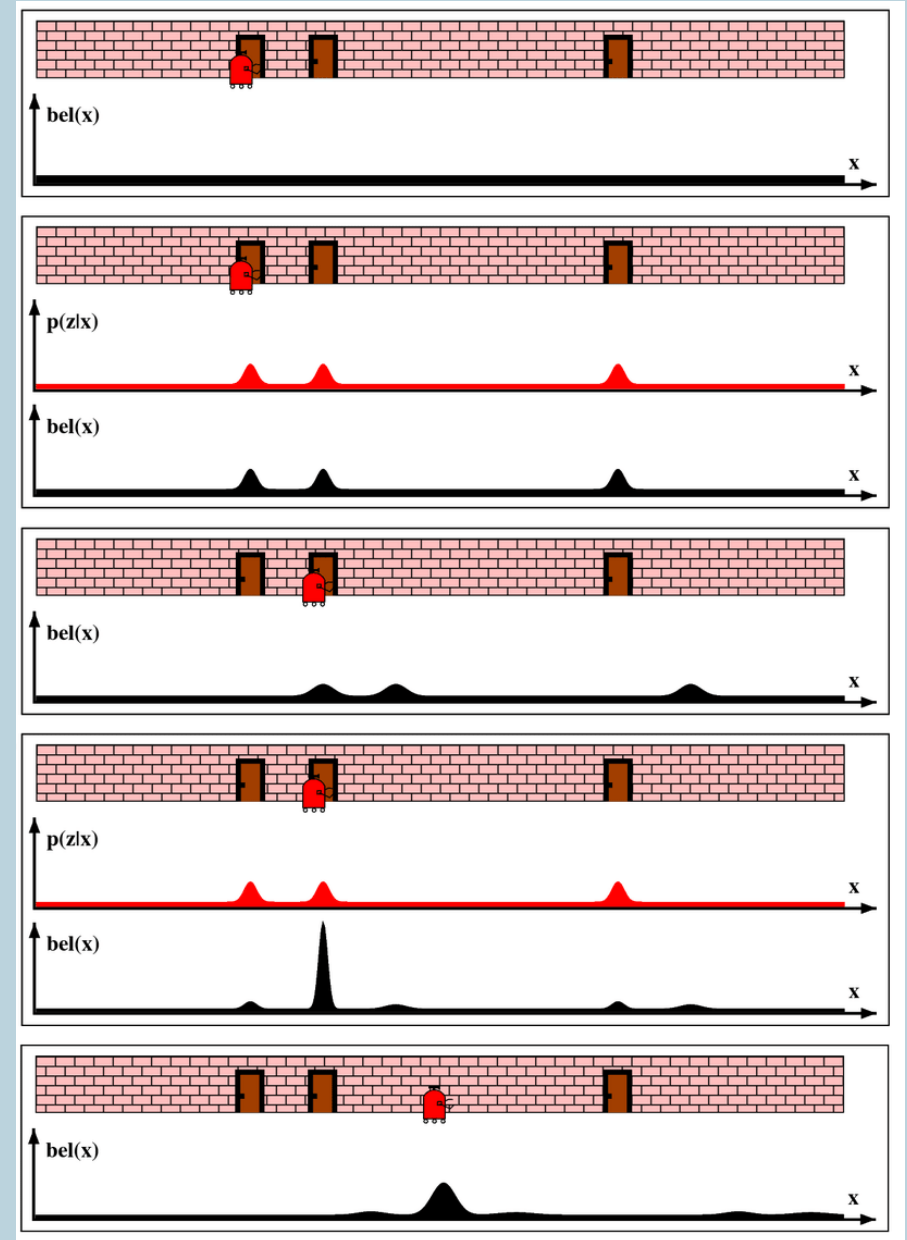
Probabilistic Robot Localization

- The robot receives another sensor reading: “you are again in front of a door”
- The likelihood of the reading ($p(z|x)$) is the same as before
- The new belief is very clear: given the two sensor readings the robot received, it should now be in front of the second door

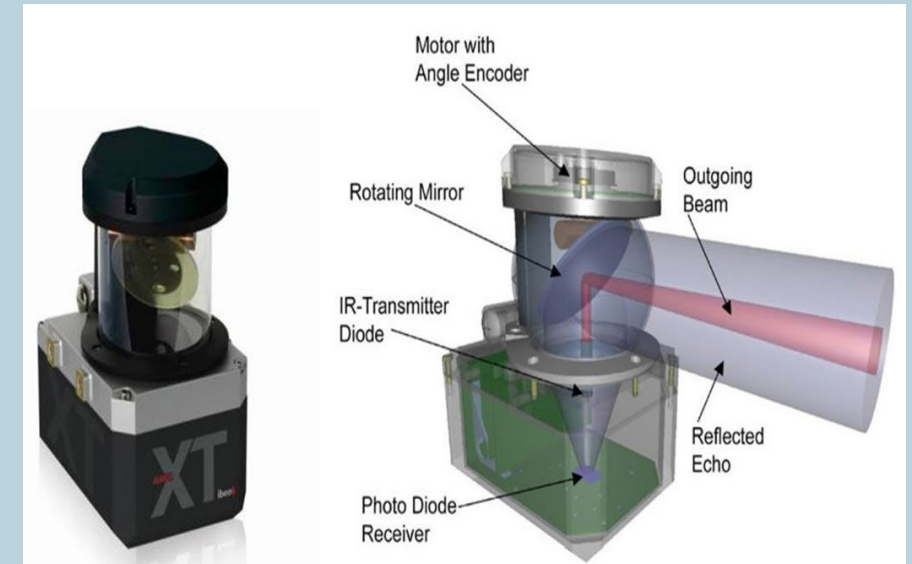


Probabilistic Robot Localization

- The correct belief can now be used to predict where the robot is along the corridor when it moves

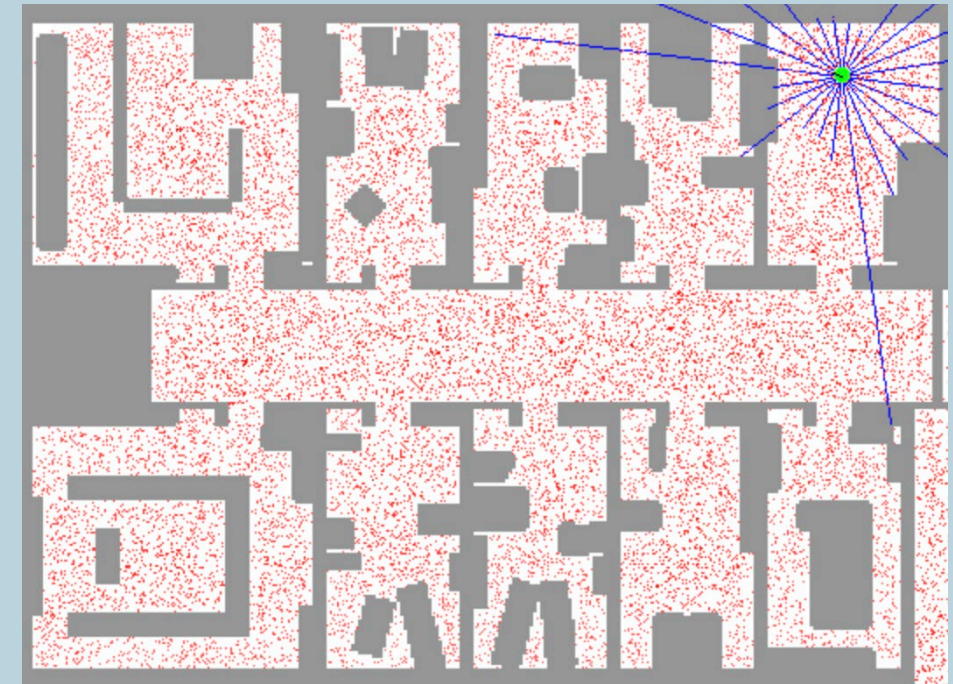


Probabilistic Robot Localization in Action

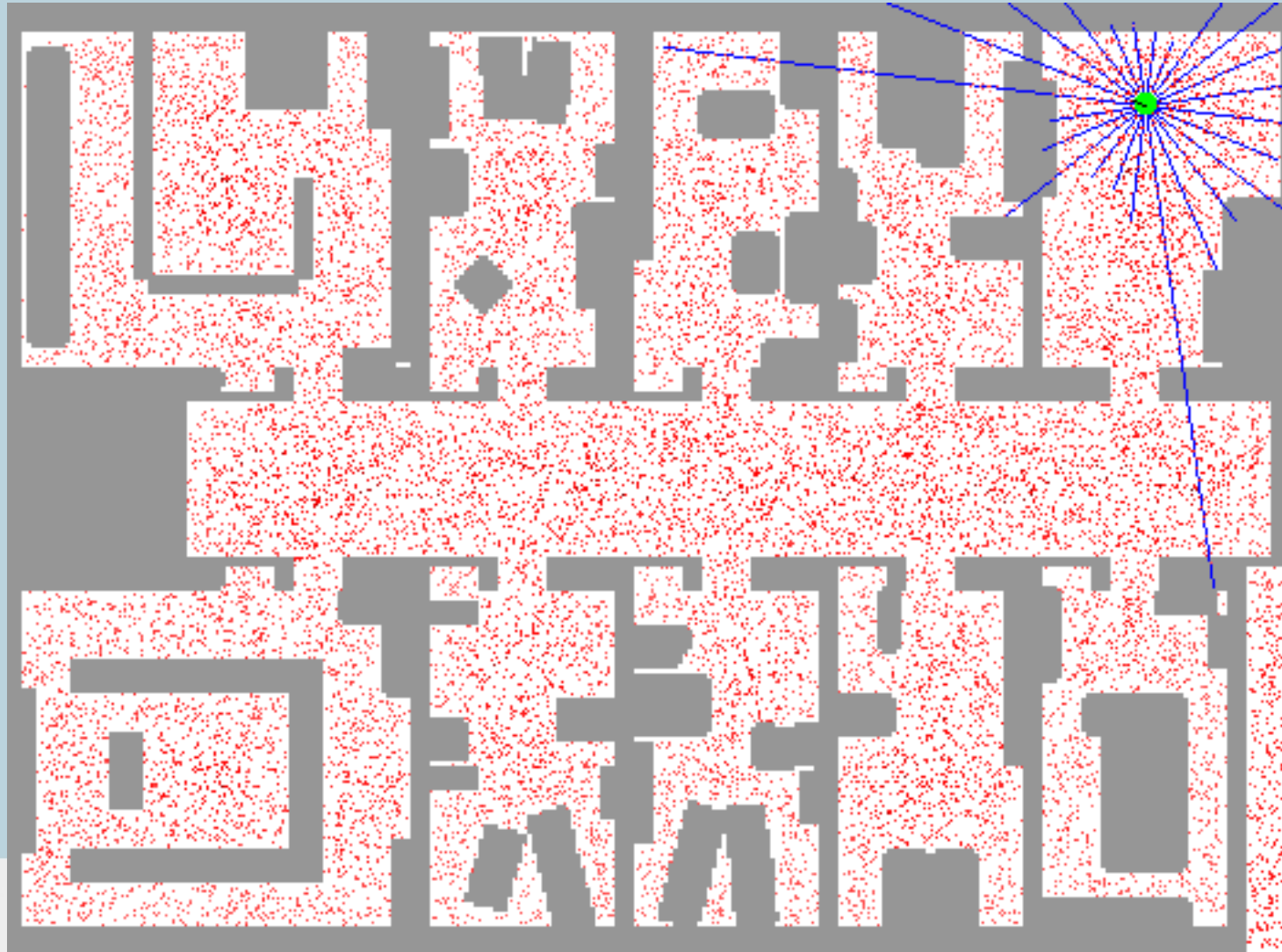


Lidar

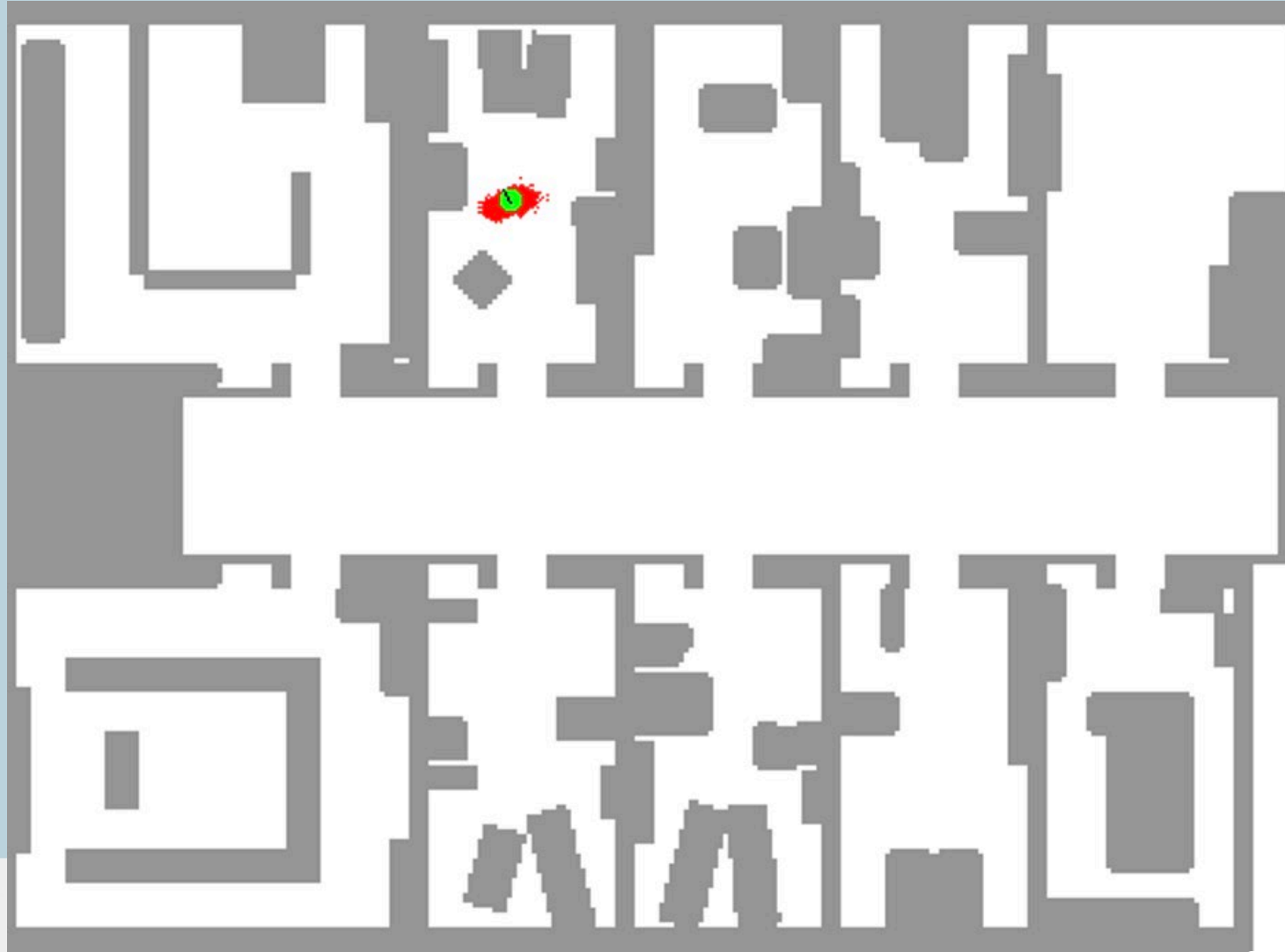
Probabilistic Robot Localization in Action



Probabilistic Robot Localization in Action



Probabilistic Robot Localization in Action

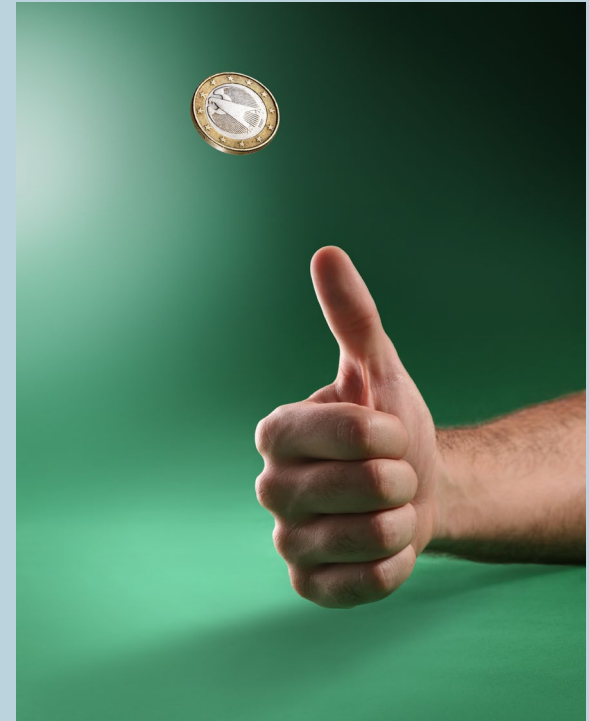


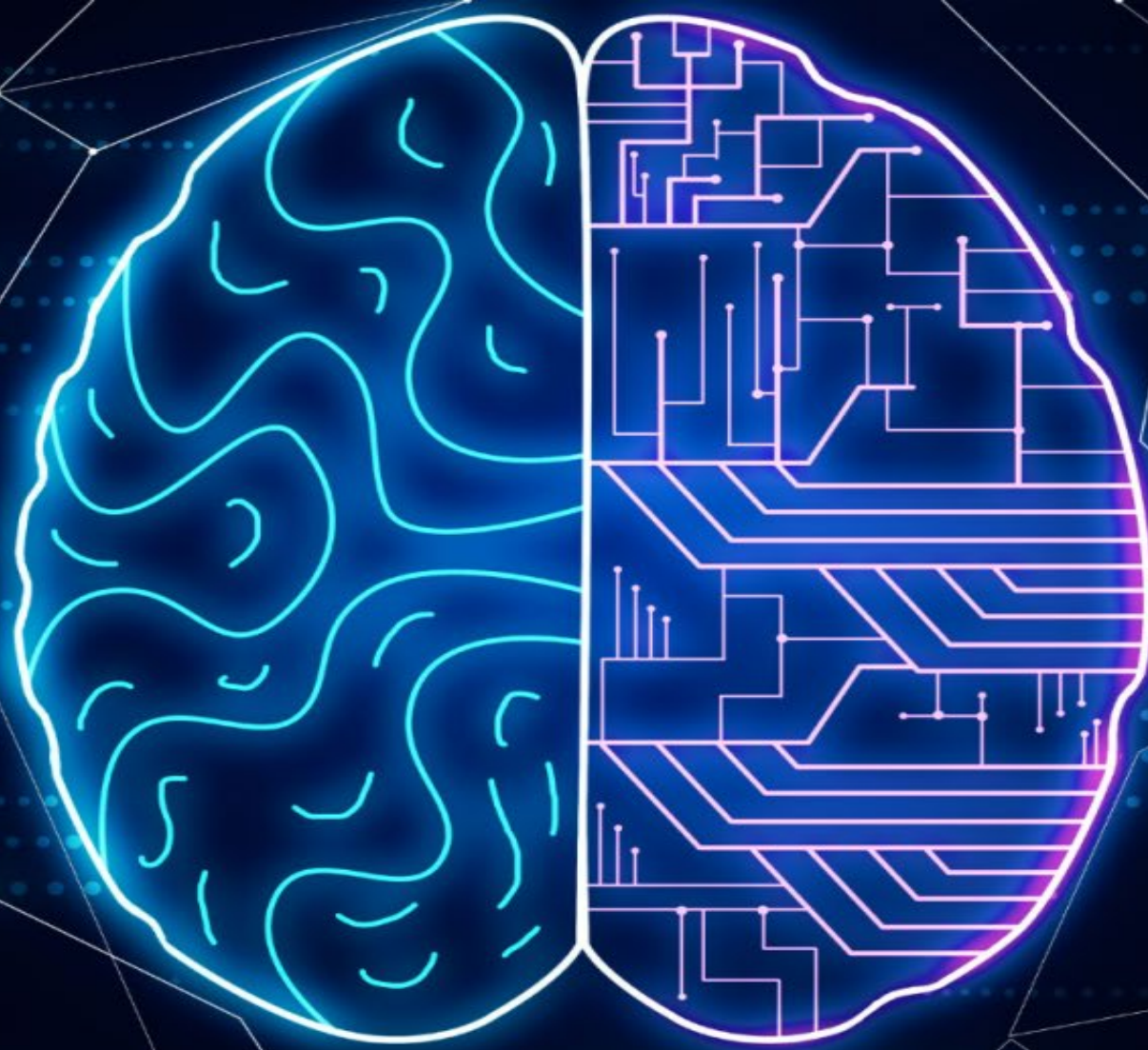
Instapoll



Summary

- Why probabilistic modeling?
- Basics of Probability
 - Random variable
 - Probability distribution
 - Dependent and independent variables
 - Correlation vs. Causation
- Bayes rule
- Probabilistic Graphical Models
- Probabilistic Robotics





Next Week: Machine Learning Fundamentals
with Adam Klivans