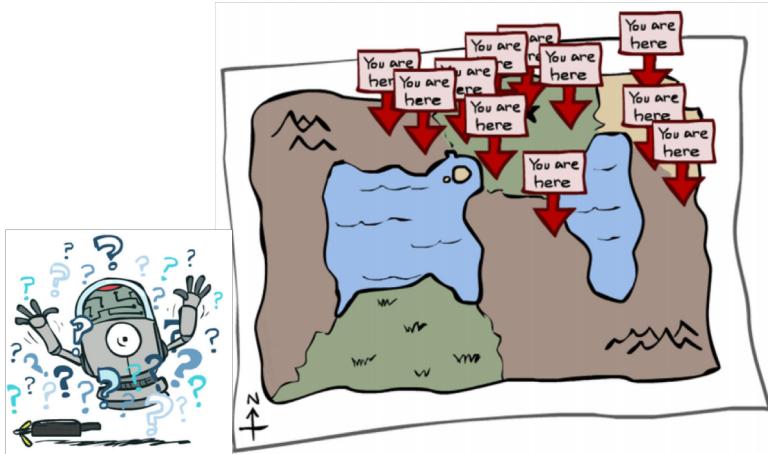


# CS 1501: Intro to Robotics

## Autonomy, AI, and Applications

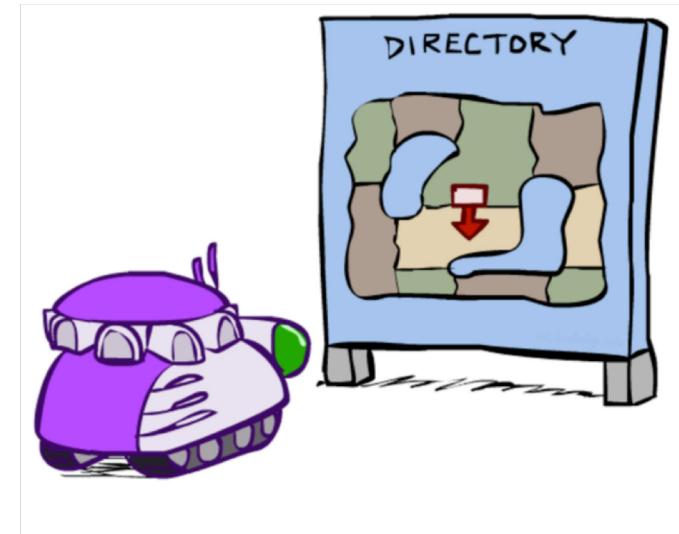
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### Localization I



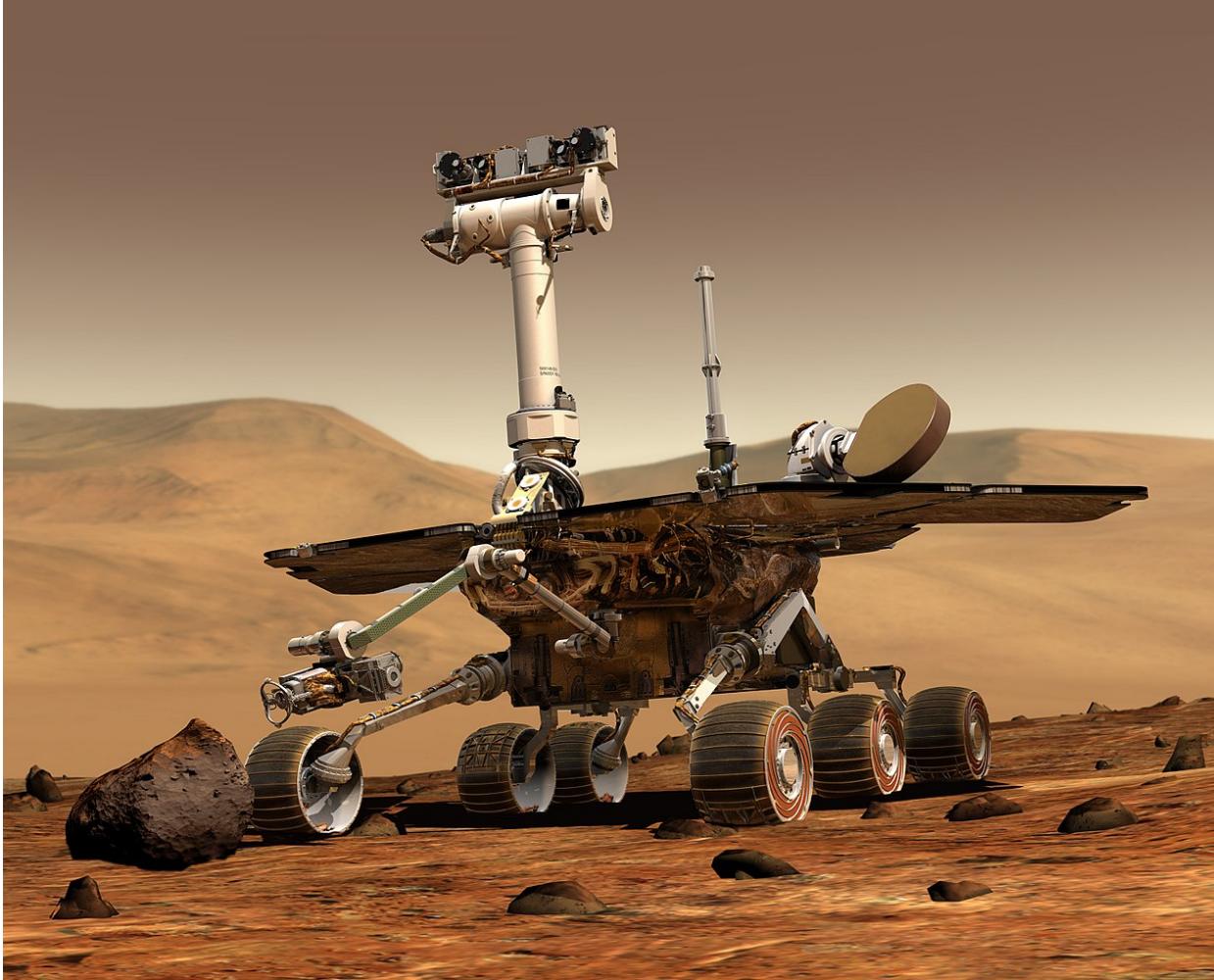
Rohan Raval

Monday 1-1:50pm, MEC 213



# RIP Oppy (2004-2018)

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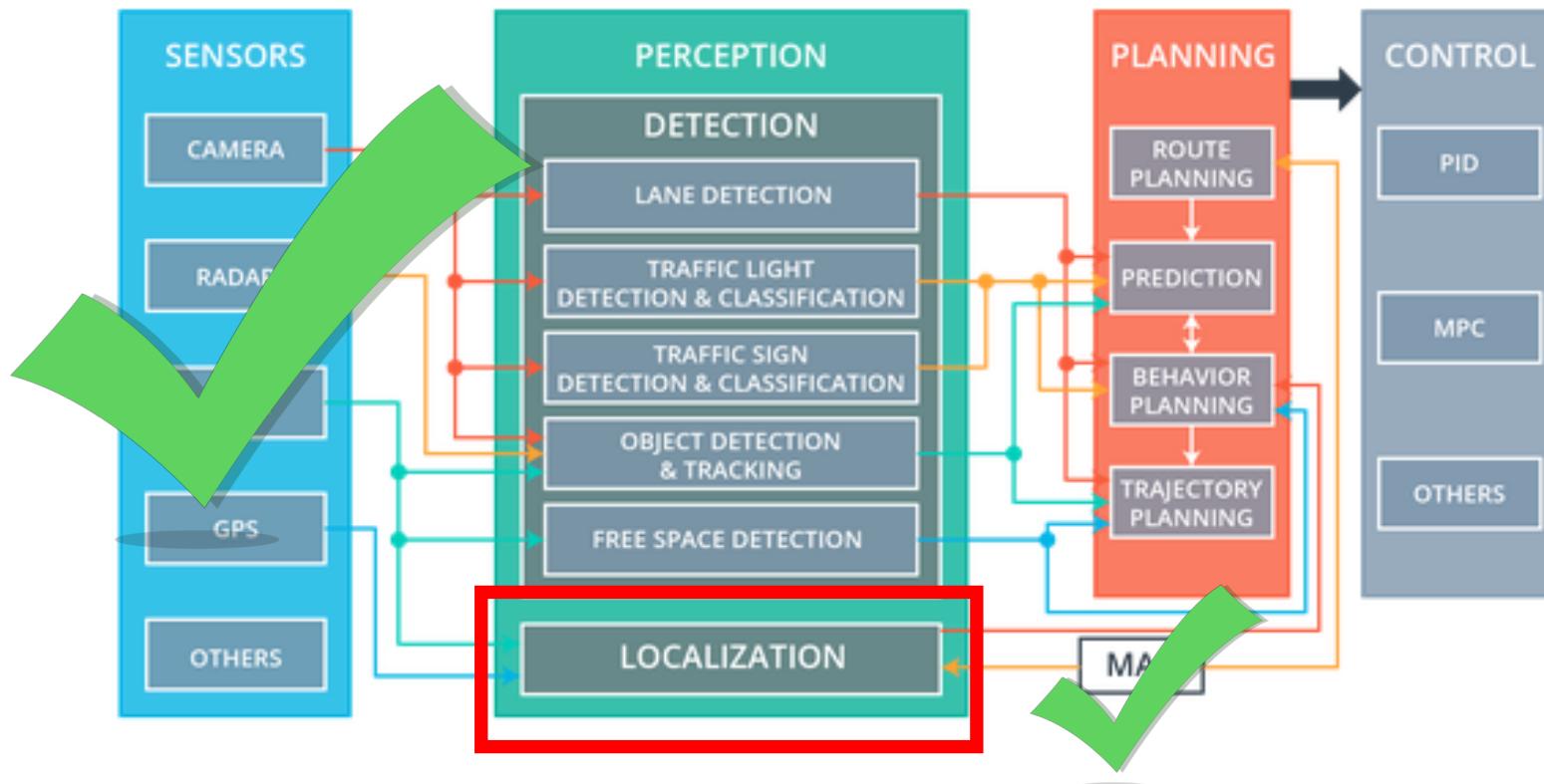
# Childhood Ruined?

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# Recap: See-Think-Act

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# Localization: Motivation

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- Goal: get from point A to point B
- Does the robot need to know where it is?
- Behavior-Based Navigation
  - “Follow the left wall”
  - How to detect goal is reached?



# Localization: Motivation

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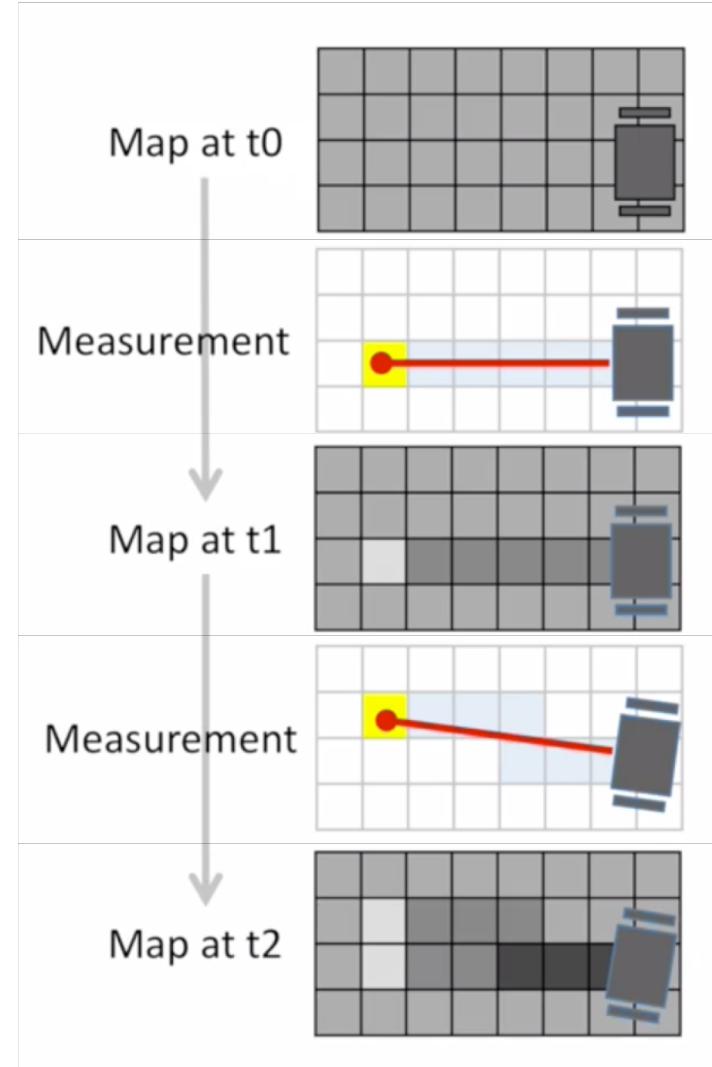
- Map-based Navigation
  - Robot needs to maintain where it is in a “map” = **Localization**
  - Do we know starting position?
  - How do we represent the map?
  - How do we represent the position within the map?
  - Landmarks/Features?
- Global Localization
  - Don’t know initial position, start from scratch
- Position Tracking
  - Know initial position, maintain it while moving



# Recap: Maps

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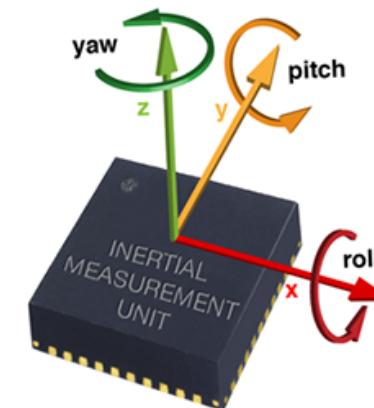
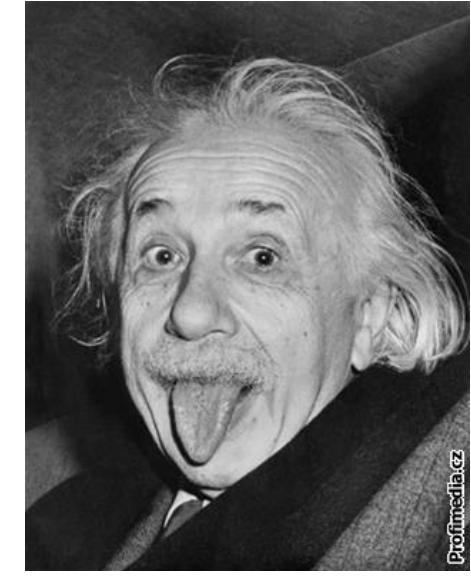
- Challenges of Maps
  - Dynamic Environment
  - Motion
  - Reference Frames: Robot to Global
- Occupancy Grid Mapping
  1. Prior Map
  2. Measurement
  3. Update (Posterior)
  4. Measurement
  5. Update (Posterior)
- HD Maps
  - Layered Maps
  - Storage and Retrieval



# How to Represent Localization?

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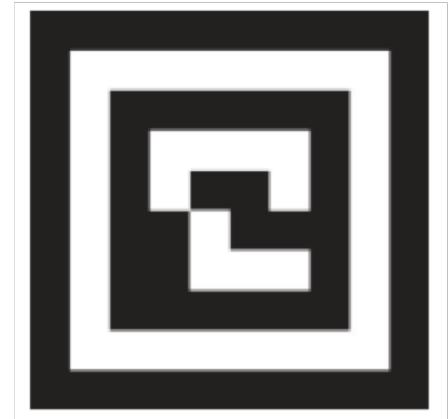
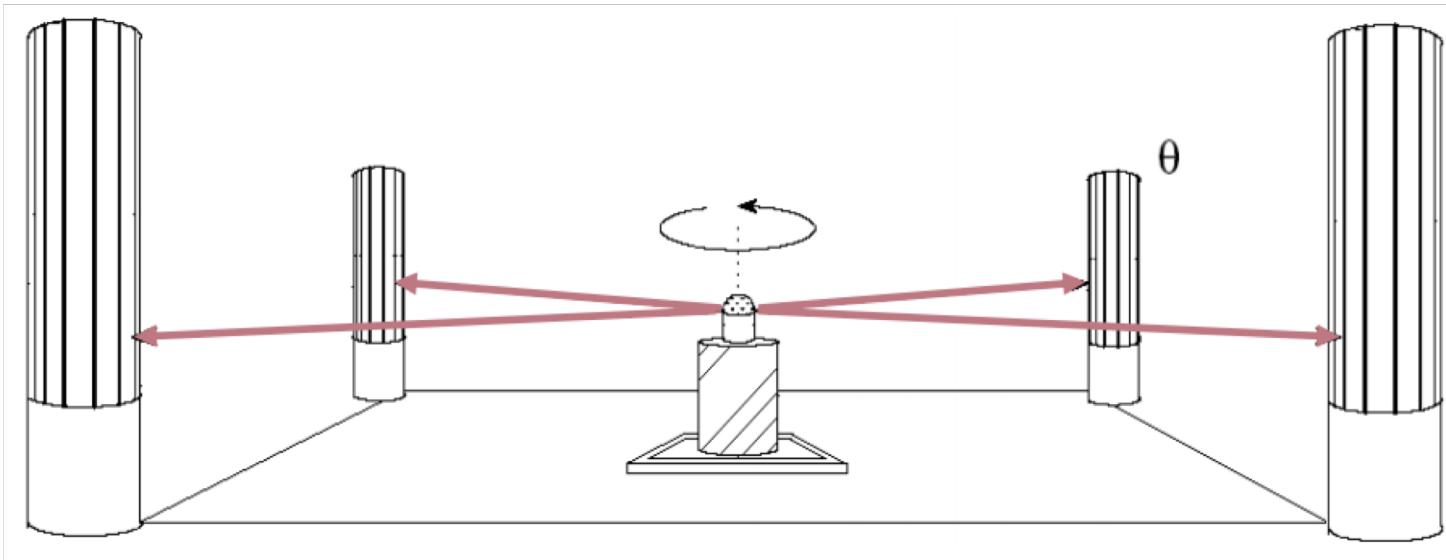
- Reference Frames
  - Robot reference frame
  - Global reference frame
- **Pose = translation and rotation**
- Representations of Pose
  - Euler Angles, Quaternions, Homogeneous Transforms, etc....
- 6 Degrees of Freedom (DoF)
  - X, Y, Z, Roll, Pitch, Yaw



# How to Localize?

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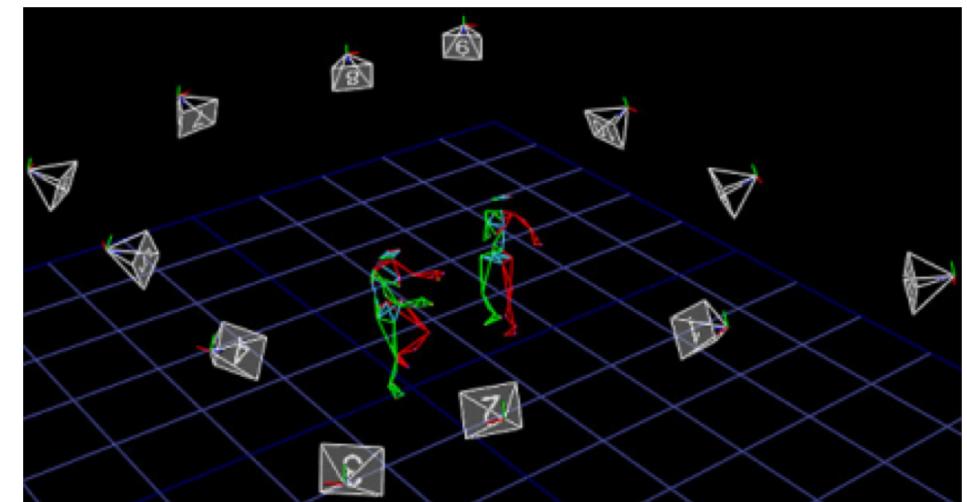
- Beacon-based Localization
  - Triangulation
  - [Kiva Systems](#)



# How to Localize?

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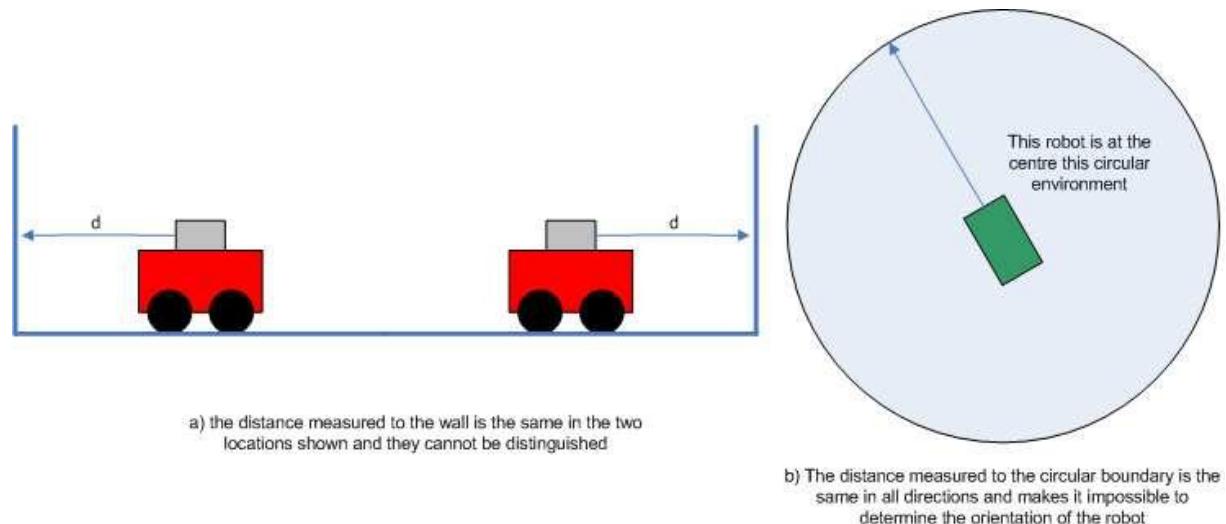
- Motion-Capture Systems



# Challenges of Localization

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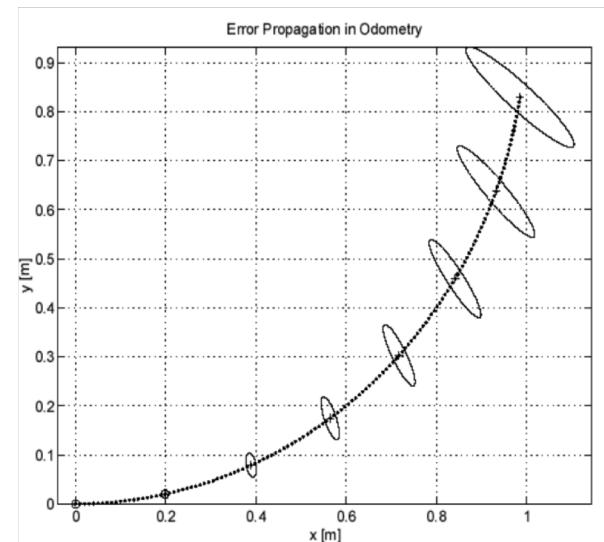
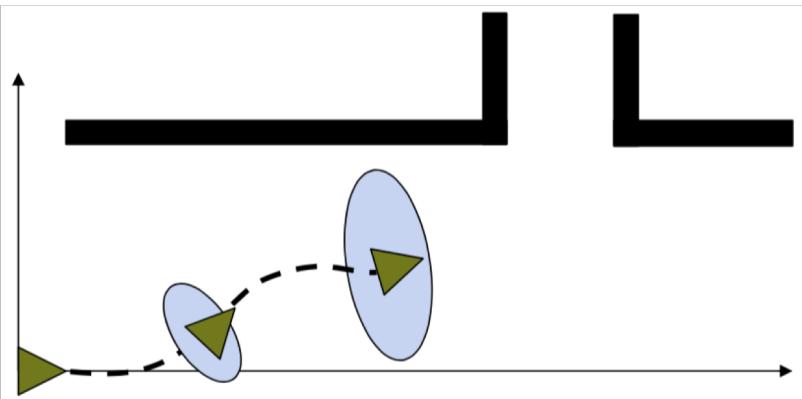
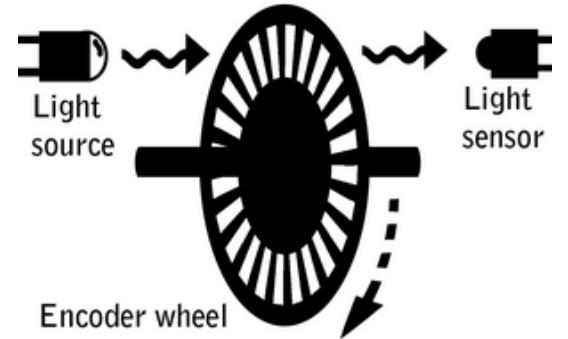
- Type of Information/Infrastructure
- Sensor Noise
- Sensor Aliasing (non-uniqueness)
- Effector Noise
- Odometry Error...



# Map-Based Localization 1: Dead Reckoning

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- Want to find pose
- But don't know how!
- Maybe know starting location?
- Wheel encoders? → Odometry
- Problems?
  - Drift, skid, wind, etc.
  - **Errors compound!**



# *Probabilistic* Map-Based Localization

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# *Probabilistic* Map-Based Localization

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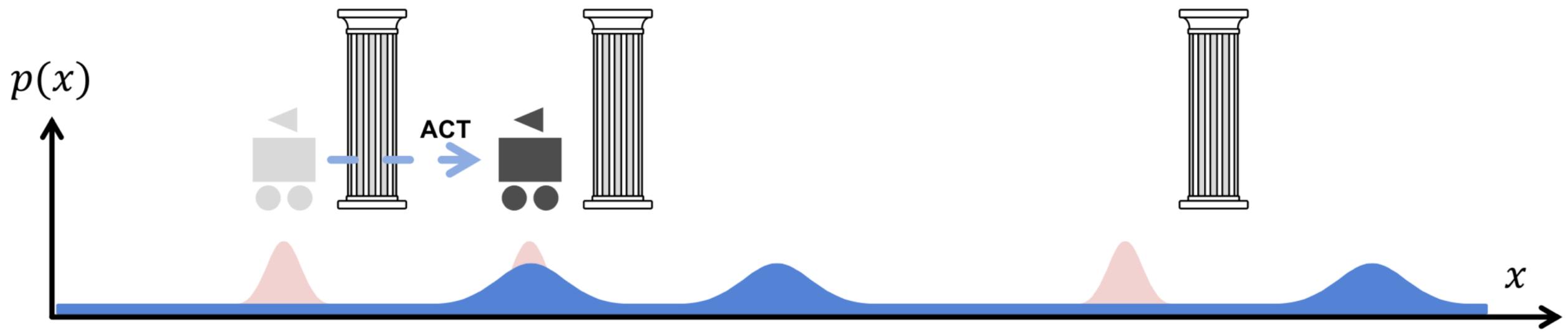
# *Probabilistic* Map-Based Localization

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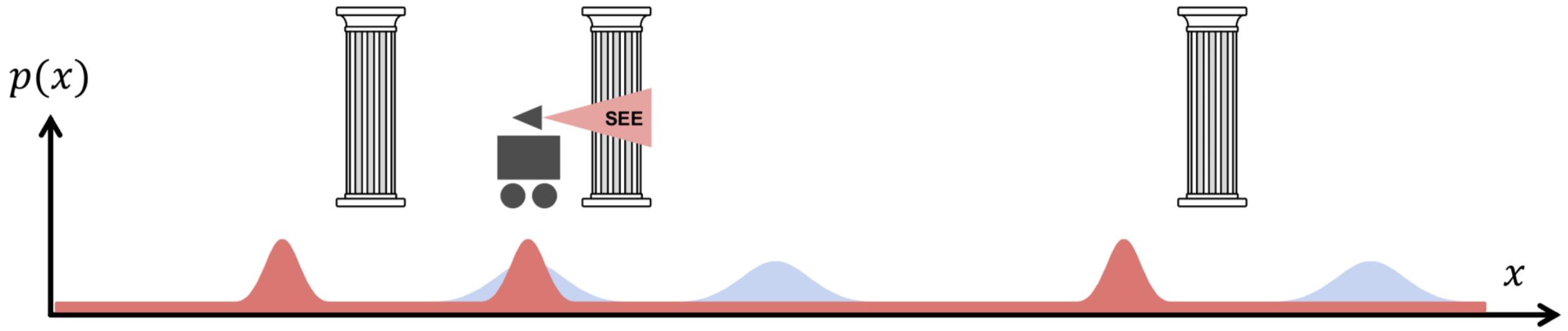
# *Probabilistic* Map-Based Localization

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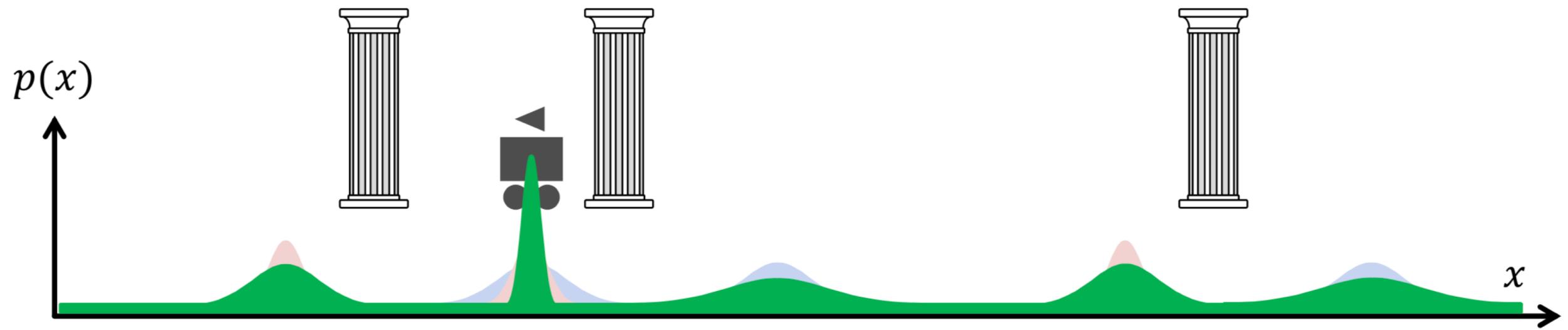
# *Probabilistic* Map-Based Localization

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# *Probabilistic* Map-Based Localization

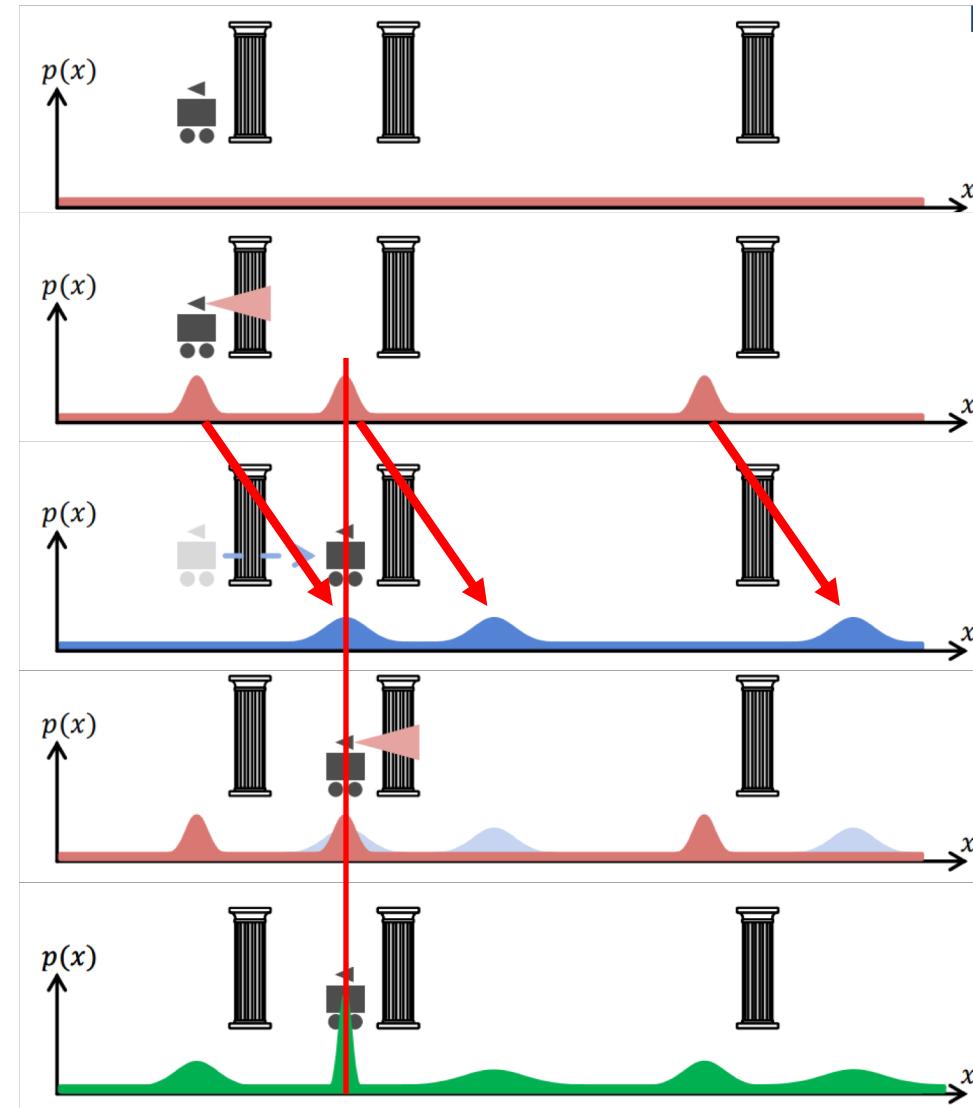
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# Histogram Filter

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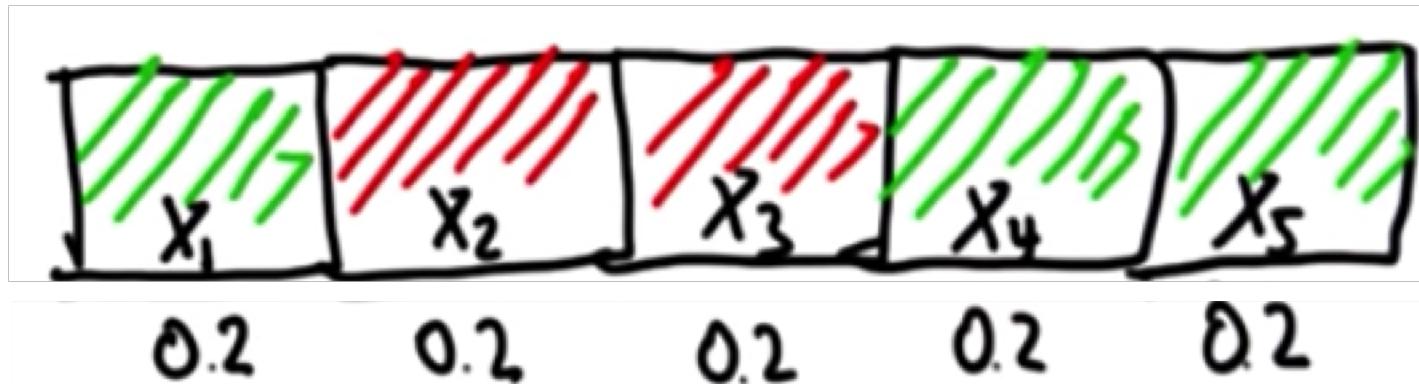
1. Initial Belief (Prior)
2. Measurement  $\rightarrow$  Update
3. Move  $\rightarrow$  Predict
4. Measurement  $\rightarrow$  Update
5. Final Belief (Posterior)



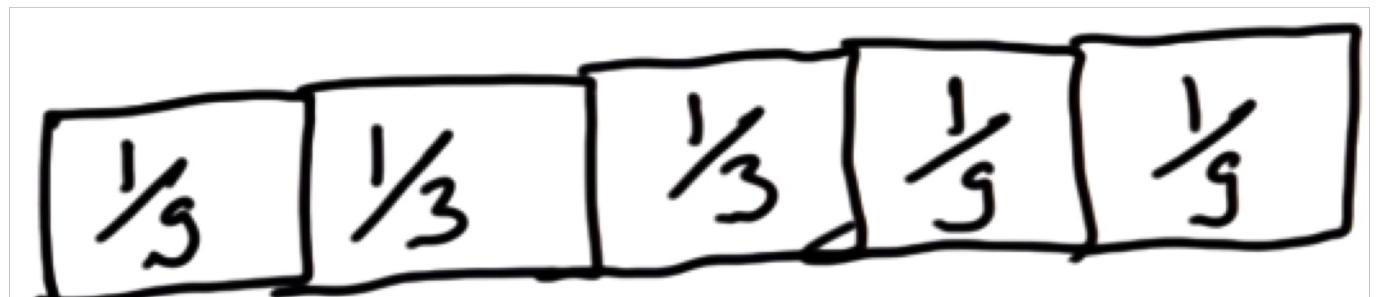
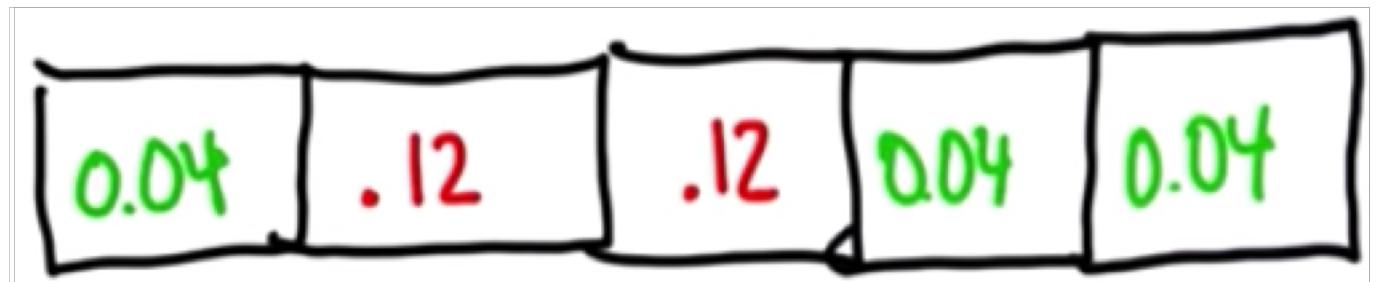
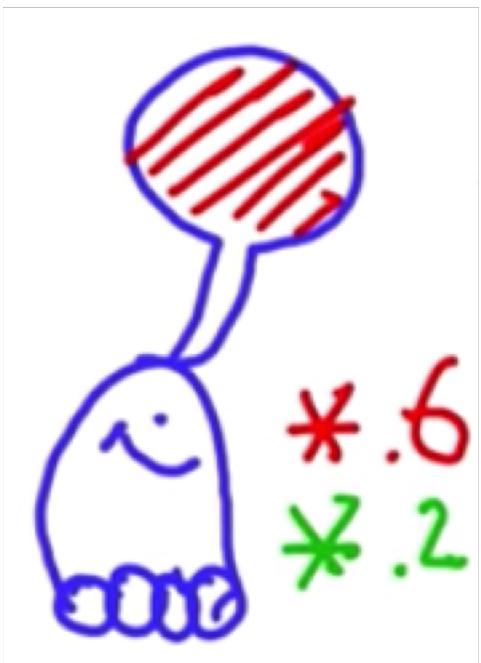
# An Example...

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1. Initial Belief (Prior)



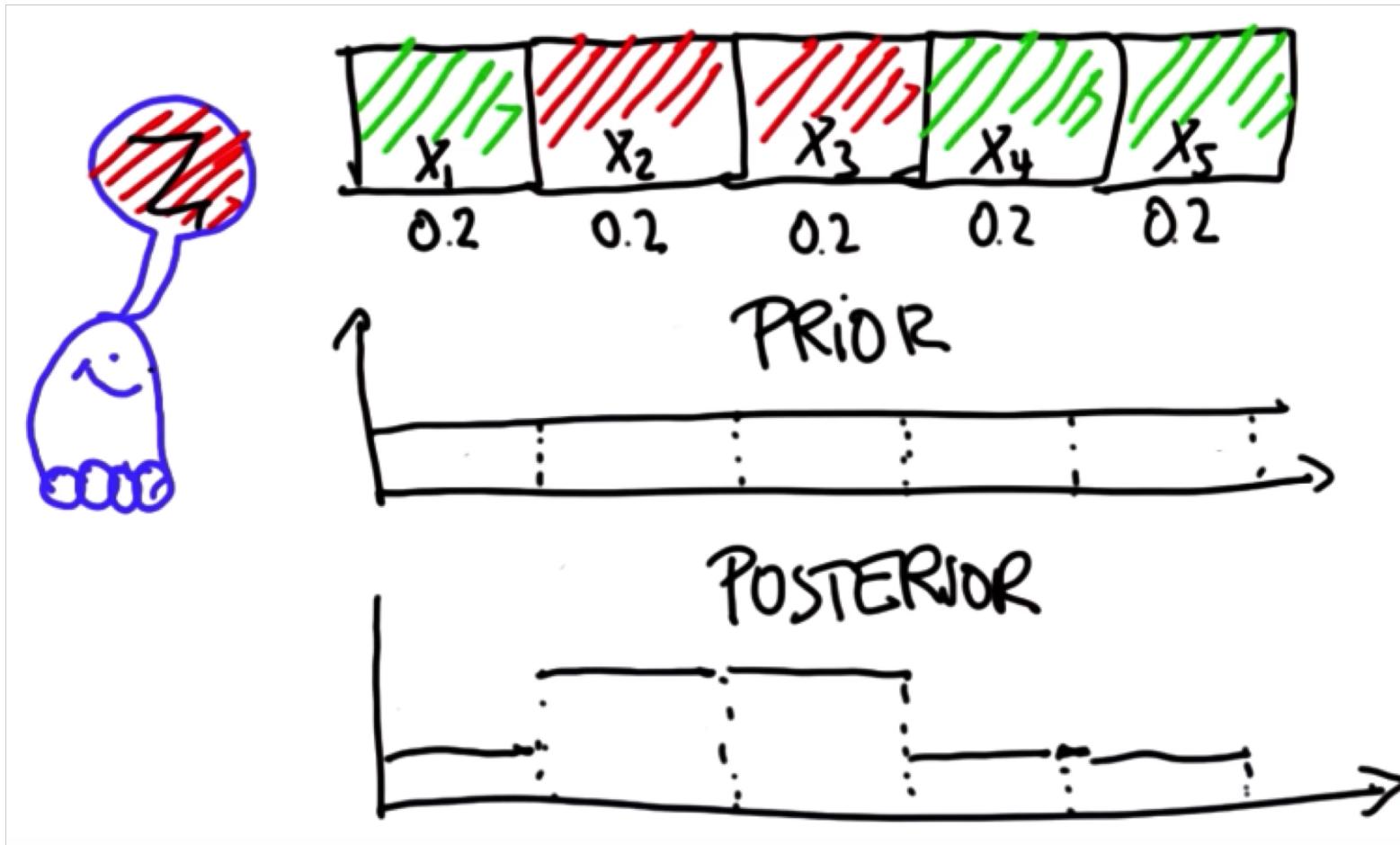
2. Measurement → Update



# An Example...

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2. Measurement → Update

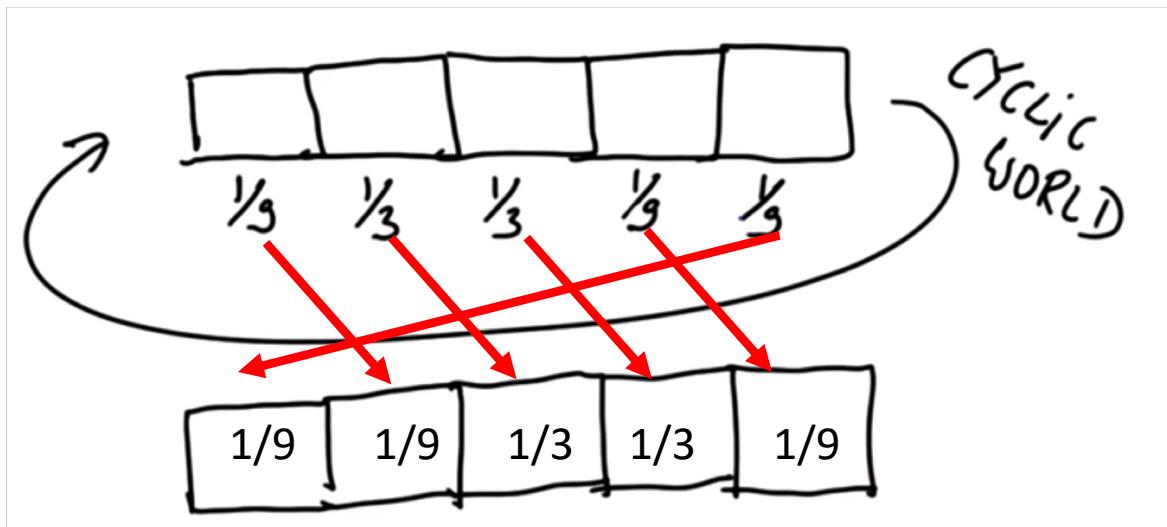


# An Example...

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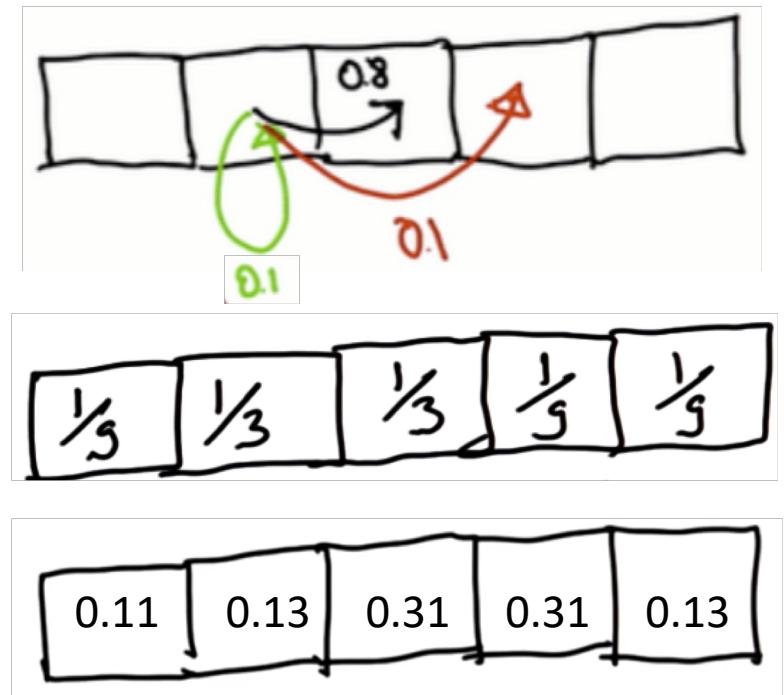
## 3. Move → Predict

Exact



**NOTE:  $0.31 < \frac{1}{3}$  !!!**

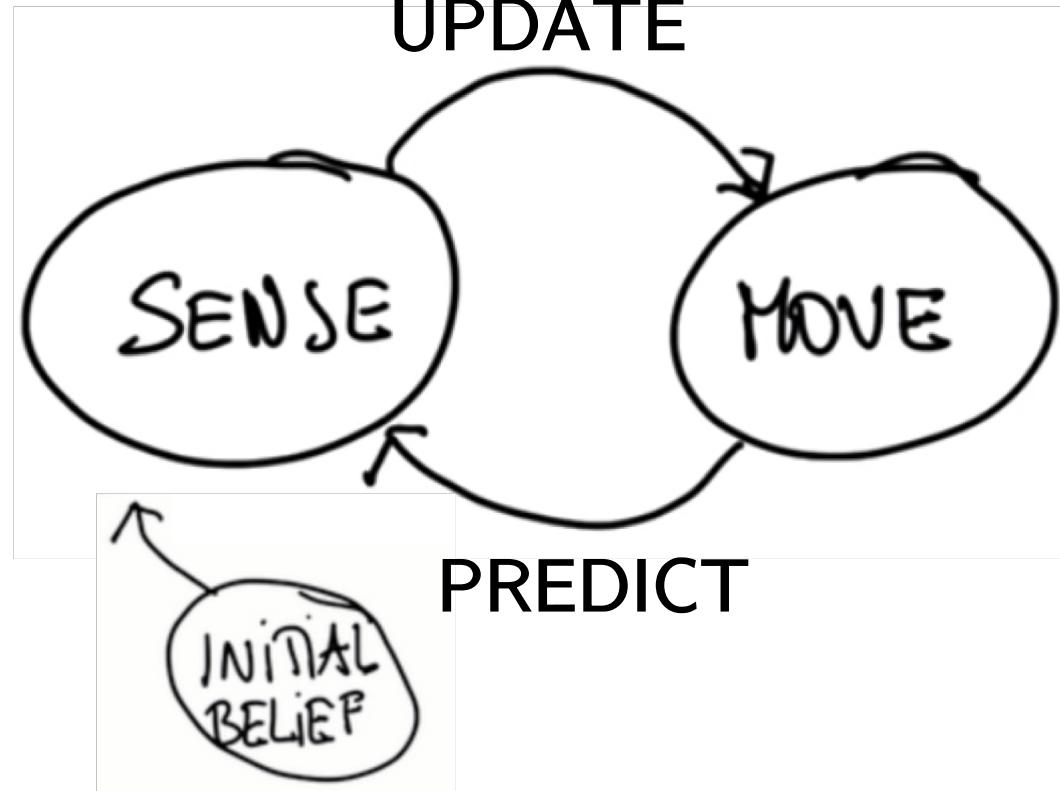
Inexact



# Predict-Update Cycle

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Gains Information



Loses Information