CS325 Artificial Intelligence
Robotics II – Navigation (Ch. 25)

Dr. Cengiz Günay, Emory Univ.

Robots with Different Degrees of Freedom

Different robots has different movements and degrees of freedom:

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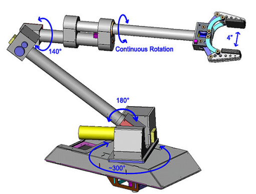
- robotic arm: only joints



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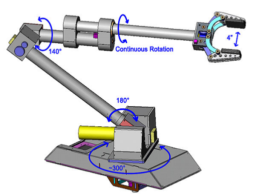

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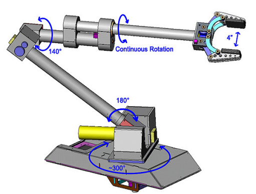

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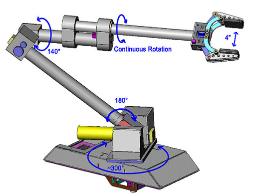

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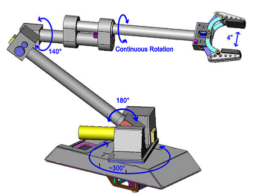

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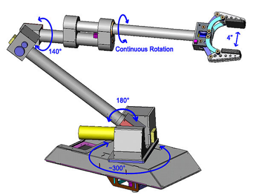

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We'll make our own self driving car :)

Entry/Exit Surveys

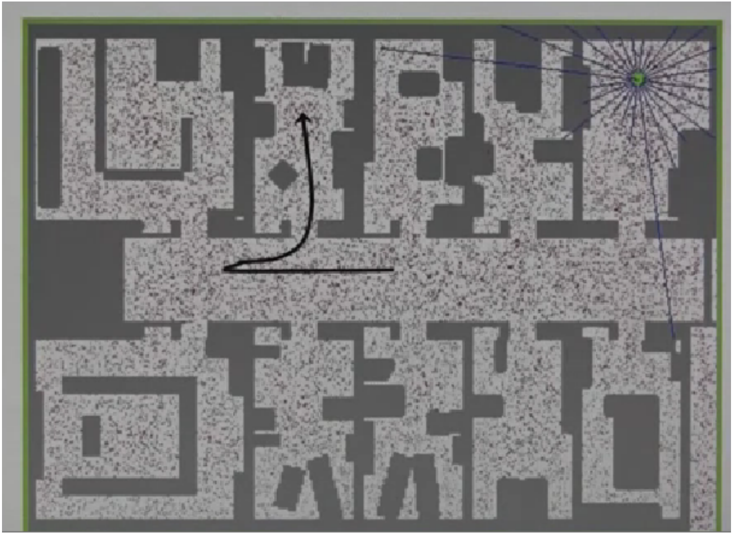
Exit survey: Robotics I – Autonomous Robots

- Which parameters do you have in the *dynamic* state of the roomba?
- How can we use the dynamic state parameters to estimate the current robot state?

Entry survey: Robotics II – Navigation (0.25 pts)

- What were the steps in the particle filter algorithm?
- In what task would a robot need to combine a particle filter with planning? Briefly explain their roles in at least one example.

Remember Particle Filters?



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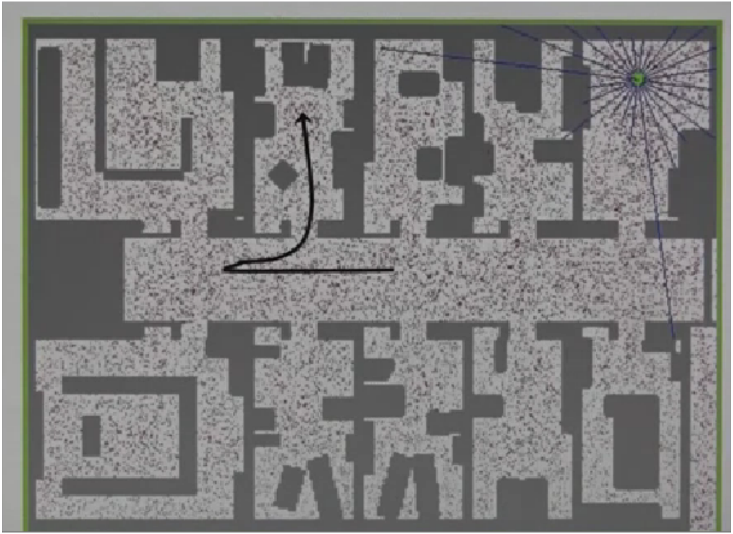
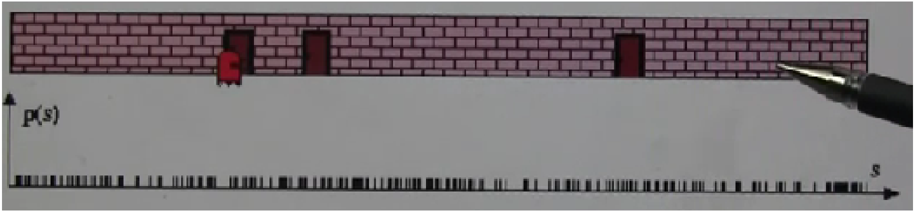


Remember why we needed location and heading in particles?

Localization with Particle Filters

Particle filtering: weights show likelihood; pick particles, shift, and repeat.



Step 1: Initialize particles from homogeneous distribution.

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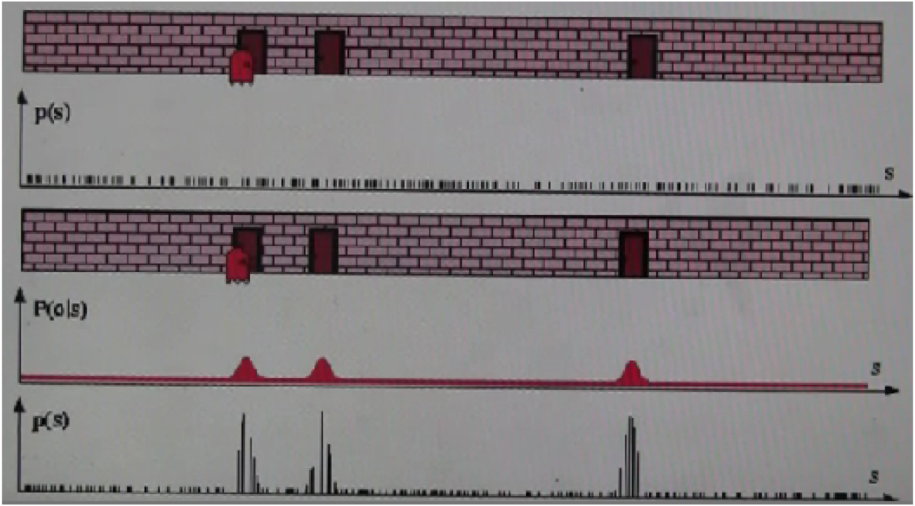
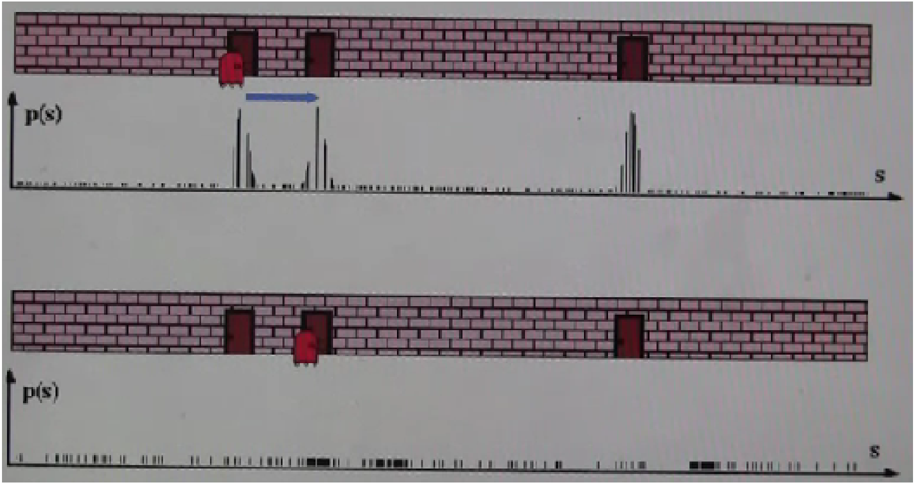


Step 2: Use sensors to **estimate likely locations**.

Particle filtering: weights show likelihood; pick particles, shift, and repeat.



Step 3: Resample likely particles and **predict next state**.

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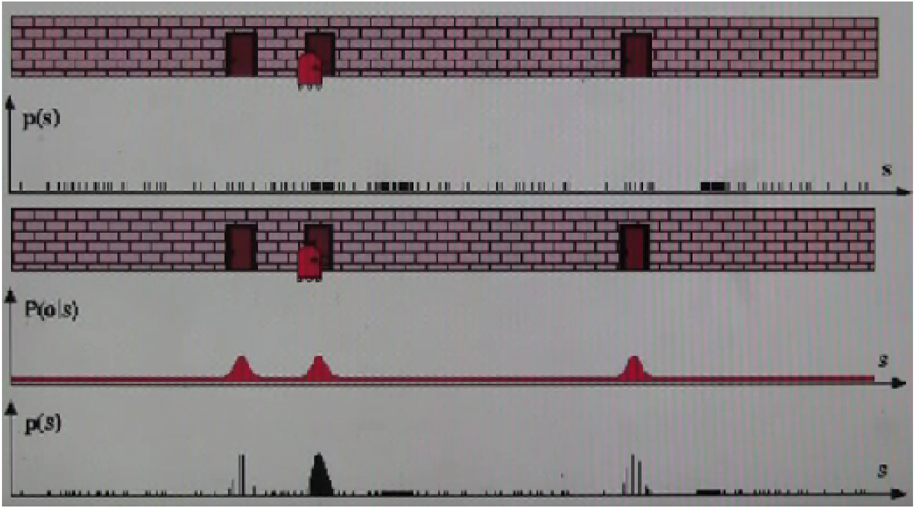

Step 4: (again) Estimate location from sensors.

Localization with Particle Filters

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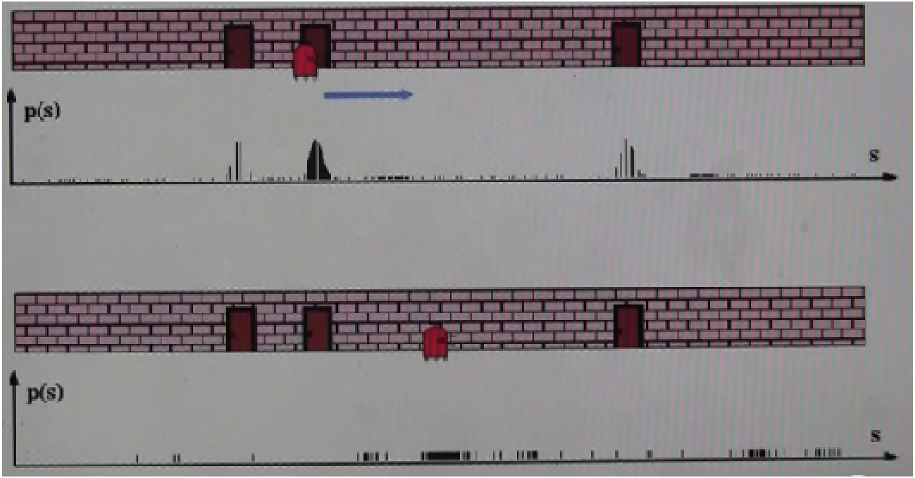


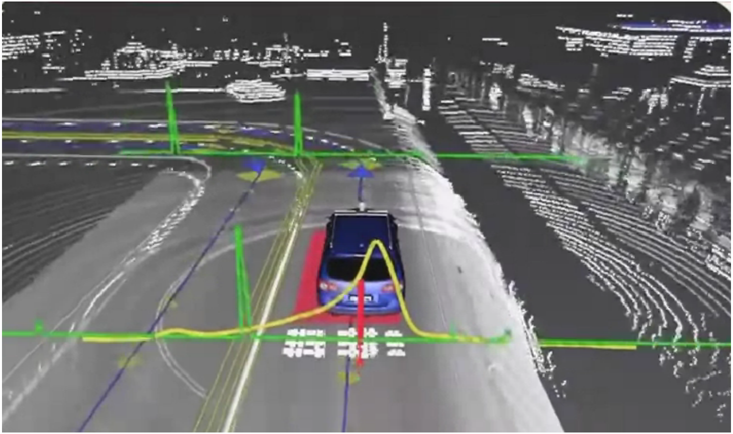
Step 5: (again) Resample and predict state from movement.

Particle Filter Algorithm

- S: Particle set $\{< x, w >, \ldots\}$,
- U: Control vector (e.g., map),
- Z: Measure vector

$S' = \emptyset,\ \eta = 0$
For i=1…n
  sample $j \sim \{w\}$ w/ replacement
  $x' \sim P(x'|U, S_j)$
  $w' = P(Z|x')$
  $\eta = \eta + w'$
  $S' = S' \cup \{< x', w' >\}$
End
For i=1…n // Normalization step
  $w_i = \frac{1}{\eta} w_i$
End

Particle Filter for Finding Road Boundaries



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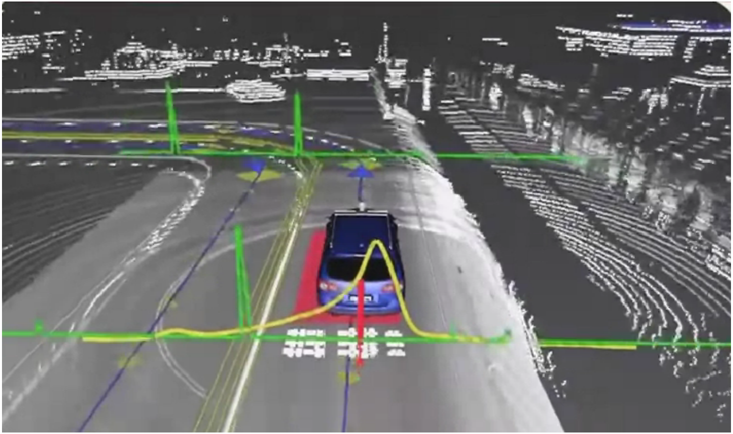

Particles following the white lane lines so the car knows where it is.

Particles are Like Small Cars

Particle's dynamic state to estimate next state:

$$\begin{pmatrix} x \\ y \\ \theta \end{pmatrix}$$

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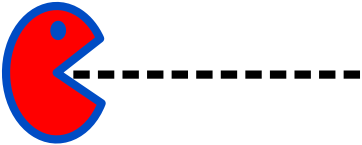

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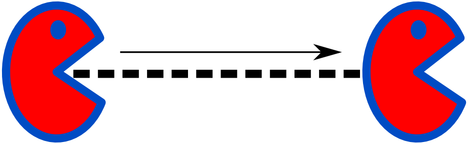

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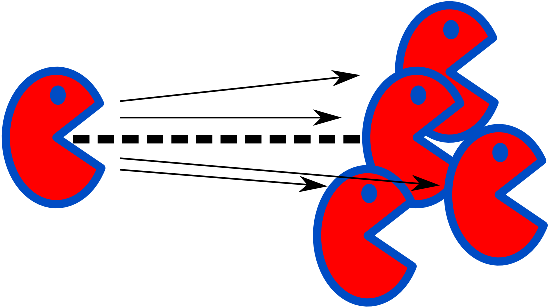

Factor In Measurements

Pacman particles try to stay on the road lines:

- Measures pattern on ground, z.

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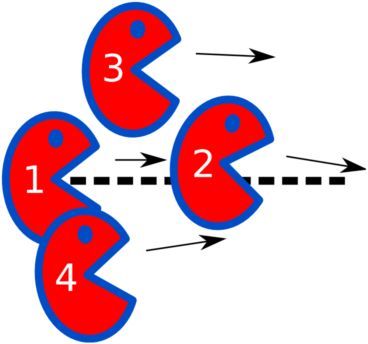

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- $P(\text{dashes}|\text{on the line}) = 0.7$

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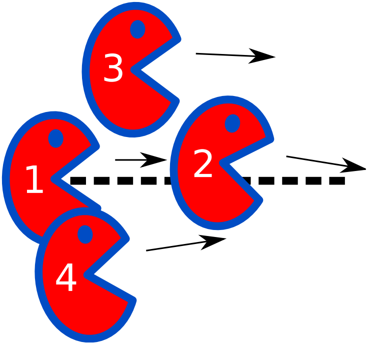

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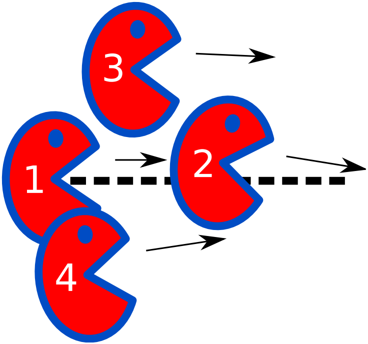

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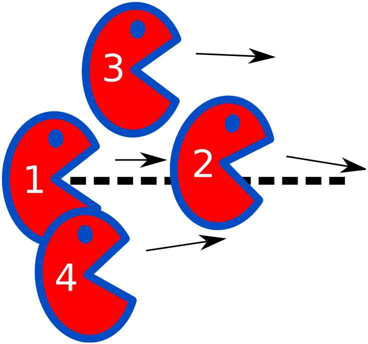

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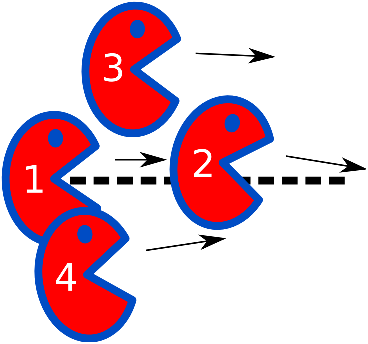

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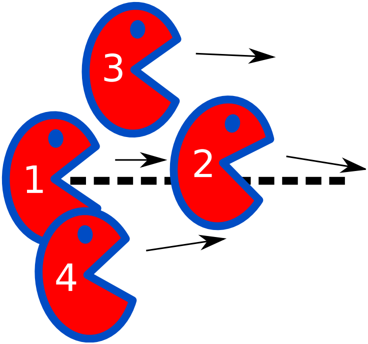

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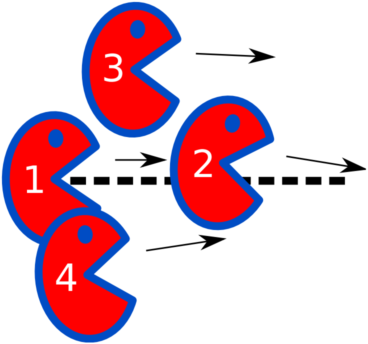

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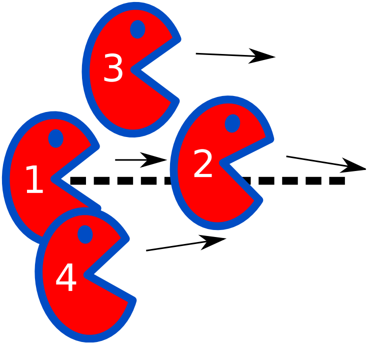

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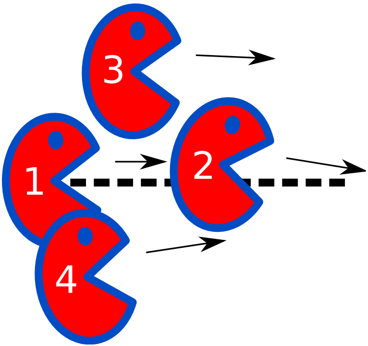

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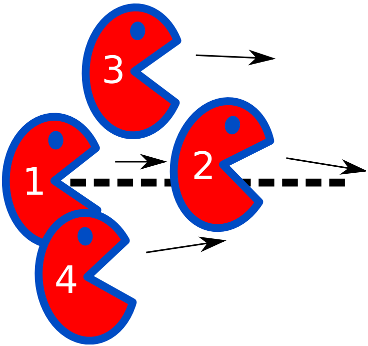

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Why? So that weights are **probabilities** that add up to 1.

Then, Resample New Particles

Pick new 4 particles based on probs:

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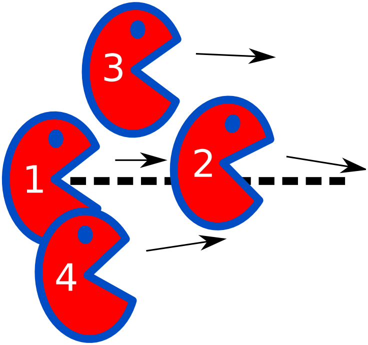

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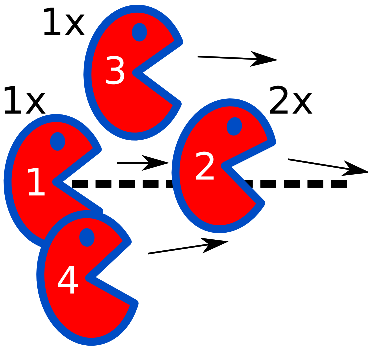

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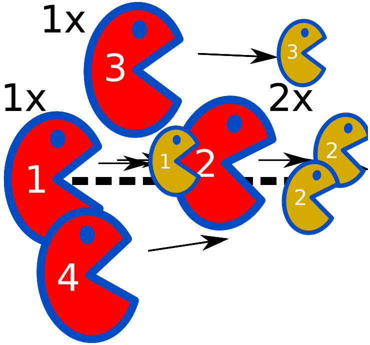

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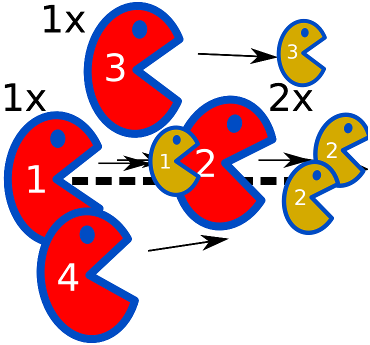

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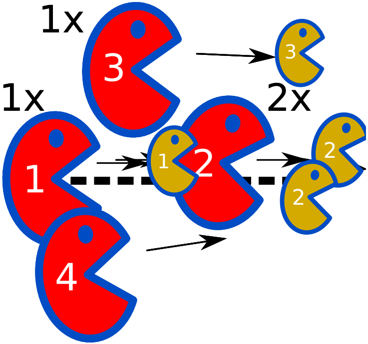

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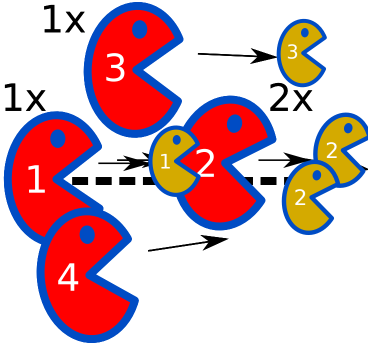

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Repeat the process:

1. Estimate
2. Measure
3. Resample

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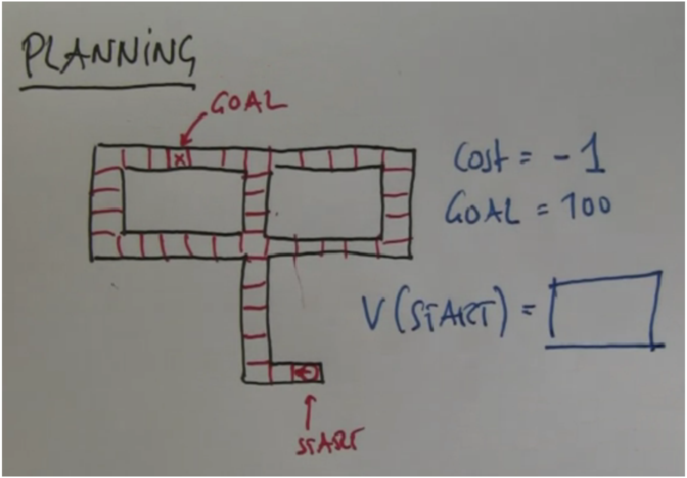

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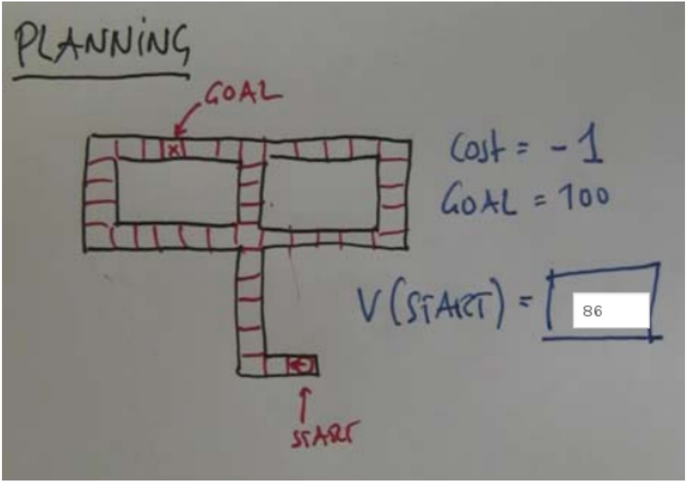
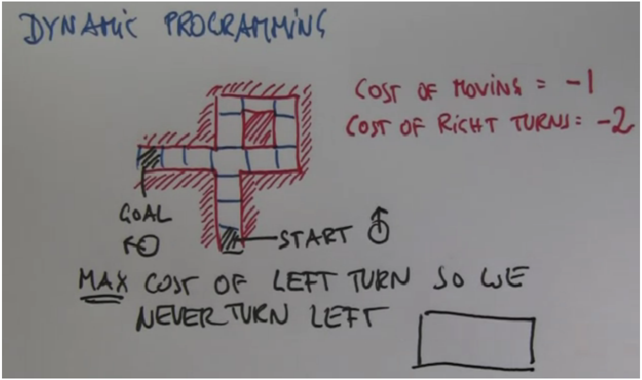


Planning: MDP in City Navigation

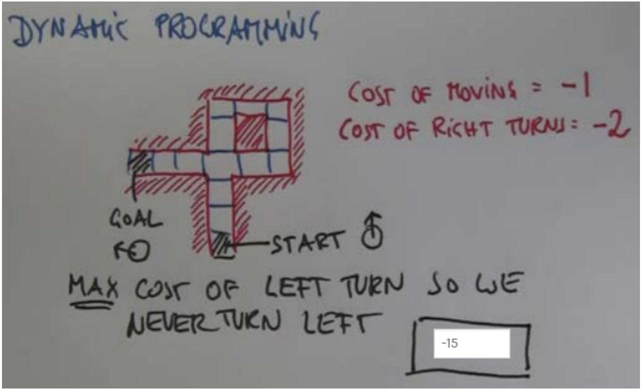
- Includes heading direction, one-way circle

MDP with Heading and Turns



(Count turns only at the intersection.)

MDP with Heading and Turns



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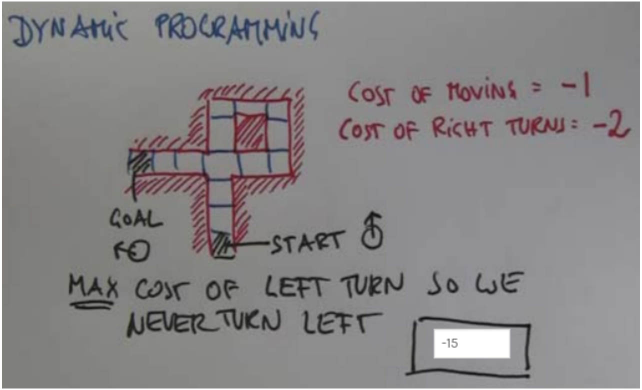

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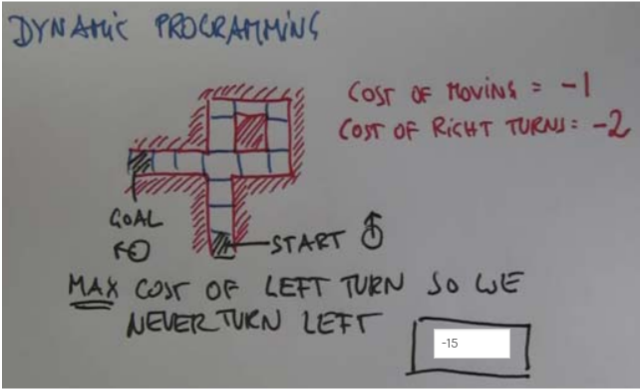
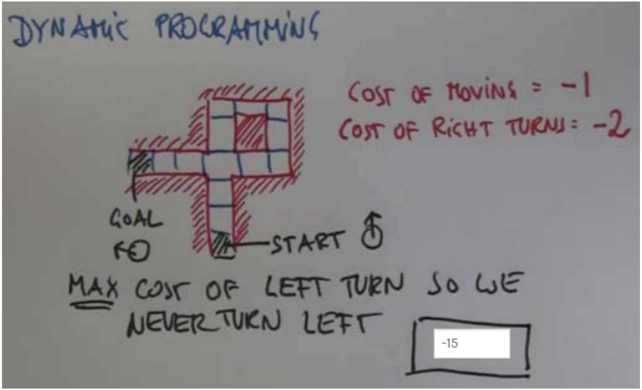


(Count turns only at the intersection.)

- Direct movement distance to goal: 6
- With the right loop:
  $6 + 8$ (additional steps) $+6$ (3 right turns) $= 6 + 14$



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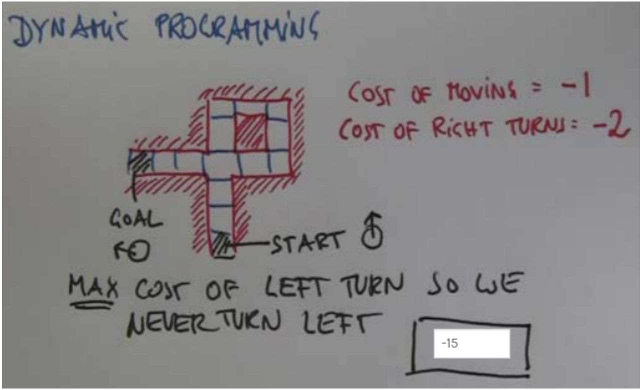
How many values per grid?

MDP with Heading and Turns



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- Direct movement distance to goal: 6
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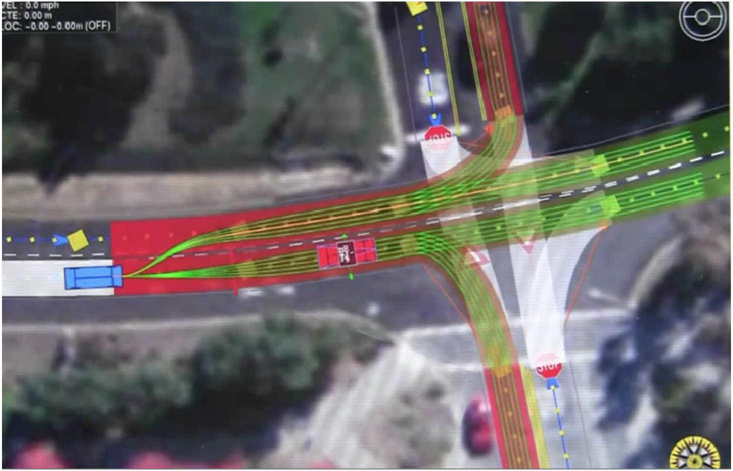
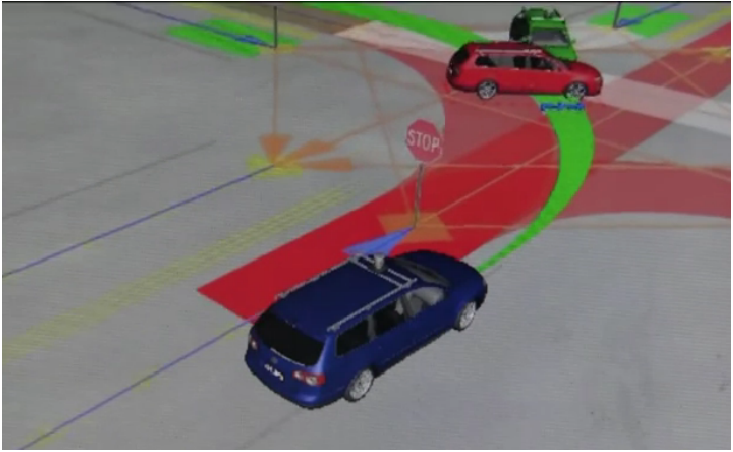
How many values per grid? More than one.

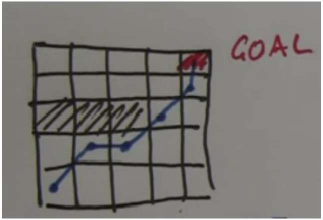
MDP in Action for Car Driving: Lane Change



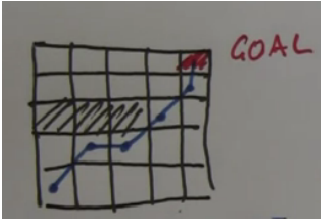
MDP in Action for Car Driving: Roadblock



A* for Robot Planning



A* for Robot Planning



Any problems with this?

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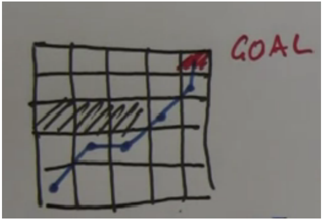
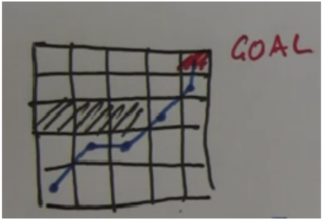


Any problems with this?

- A* is dicrete: sharp turns for car

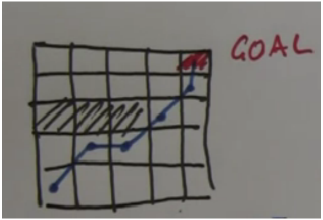
A* for Robot Planning



Any problems with this?

- A* is dicrete: sharp turns for car
- Robot car: needs continuous

A* for Robot Planning

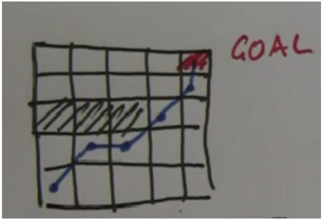


Any problems with this?

- A* is dicrete: sharp turns for car
- Robot car: needs continuous

Hybrid of discrete & continuous:

A* for Robot Planning

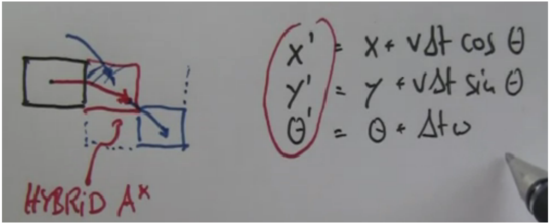


Any problems with this?

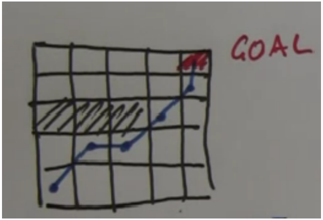
- A* is dicrete: sharp turns for car
- Robot car: needs continuous

Hybrid of discrete & continuous:

- Save location & heading within grid block.



A* for Robot Planning



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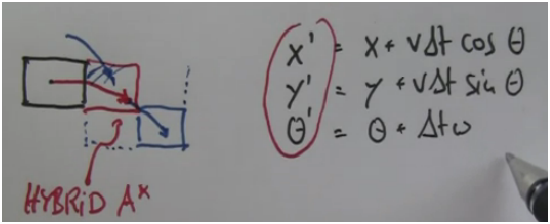
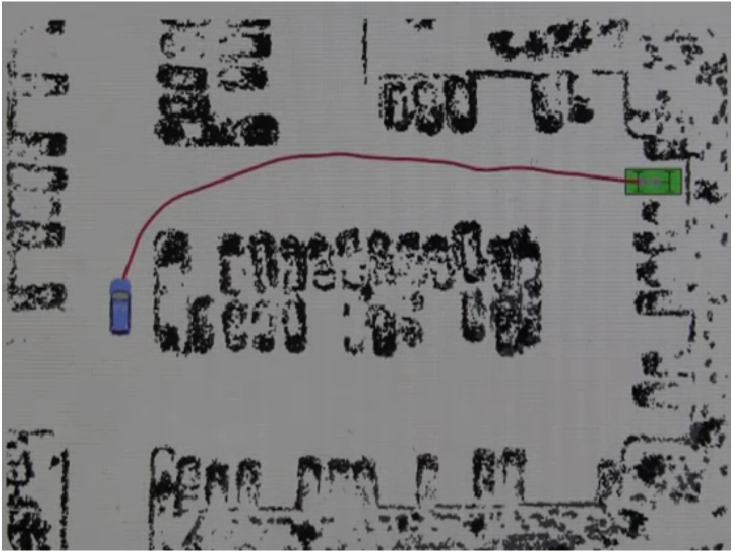


Also: prune loops, which makes it incomplete.

Hybrid A*: Driving in Parking Lot



Summary: Robotic Navigation

What we did so far:

Summary: Robotic Navigation

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Perception: Particle filter

Planning: MDP and A*

Summary: Robotic Navigation

What we did so far:

Perception: Particle filter

Planning: MDP and A*

Hope we gave you a flavor, more algorithms are also used: **Reinforcement learning**.