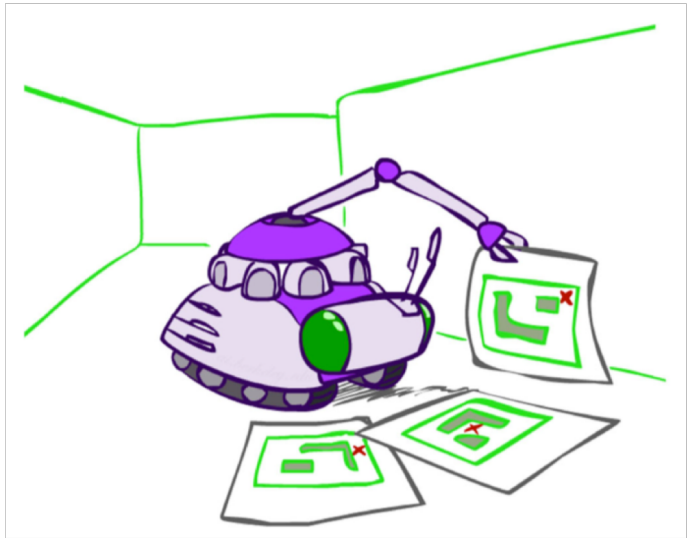
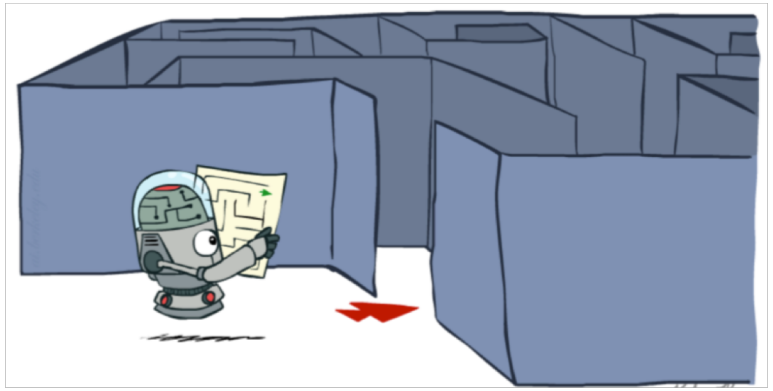
CS 1501: Intro to Robotics

Autonomy, AI, and Applications



SLAM

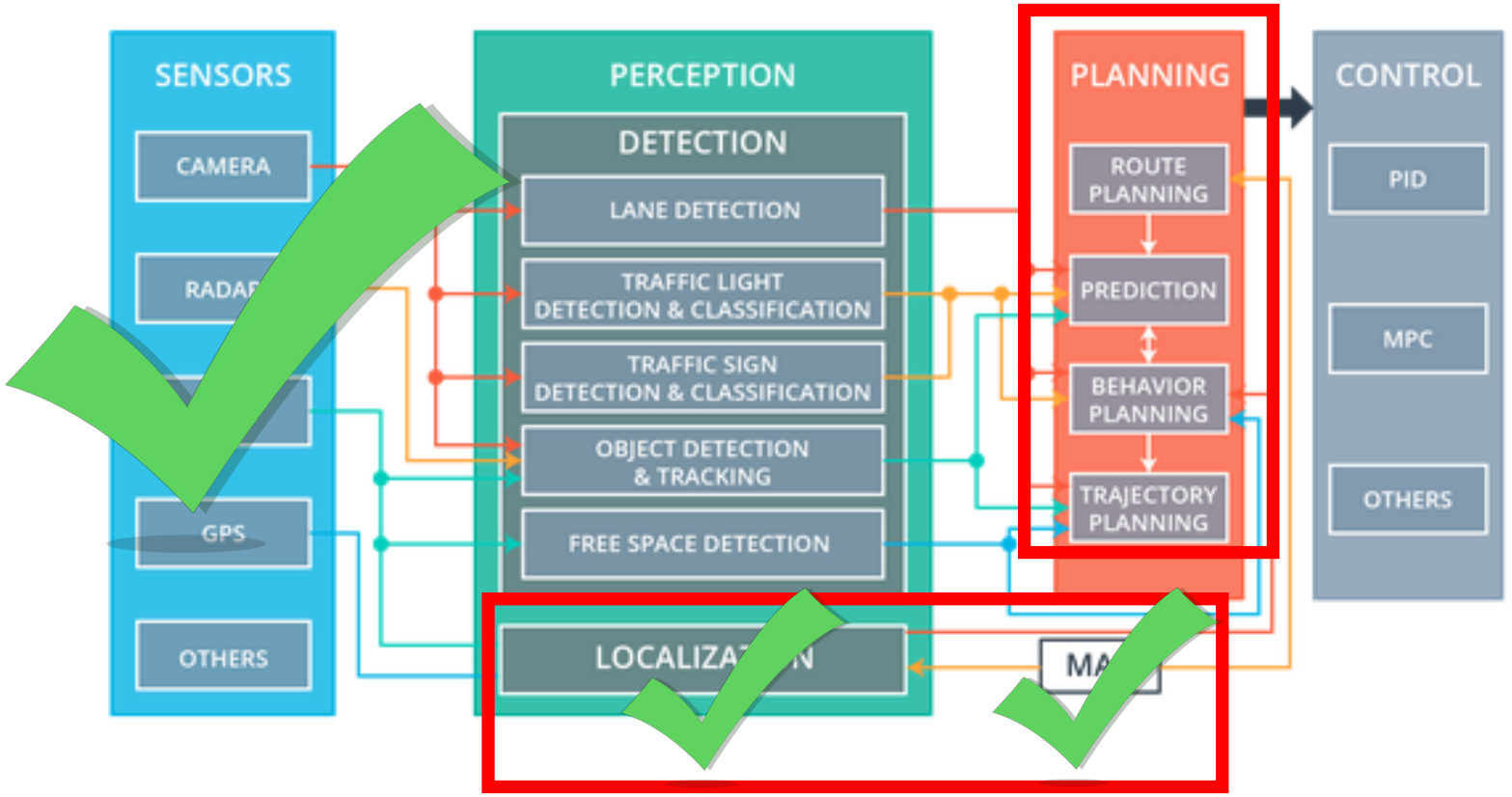
Intro to Planning



Rohan Raval

Monday 1-1:50pm, MEC 213

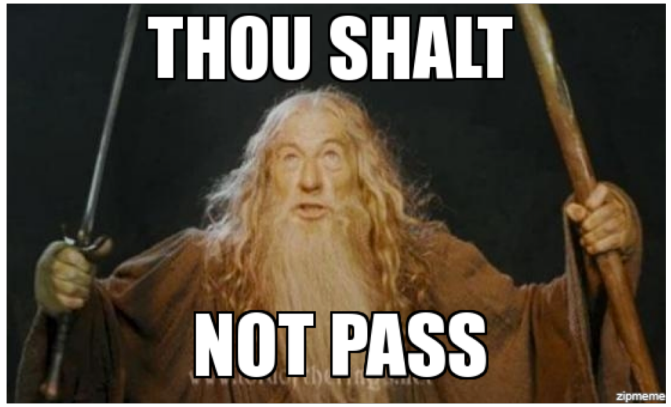
Recap: See-Think-Act



SLAM

Ultimate Goal: Autonomously get from **point A** to **point B**

But first...



Map	Location	
✓	✓	BINGO!
⊘	✓	MAPPING
✓	⊘	LOCALIZATION
⊘	⊘	SLAM!

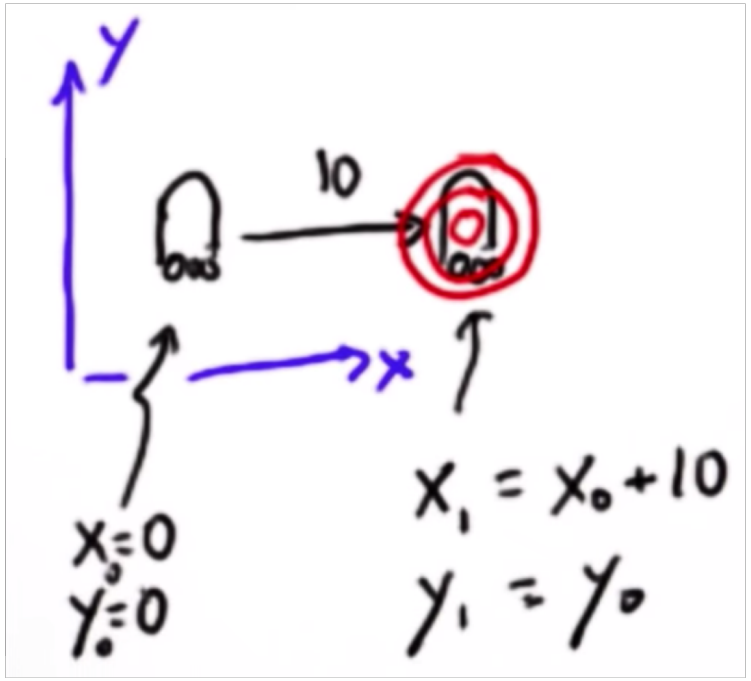
SLAM

SLAM = Simultaneous Localization and Mapping

https://www.youtube.com/watch?v=G_vtm46eGtU

Graph SLAM

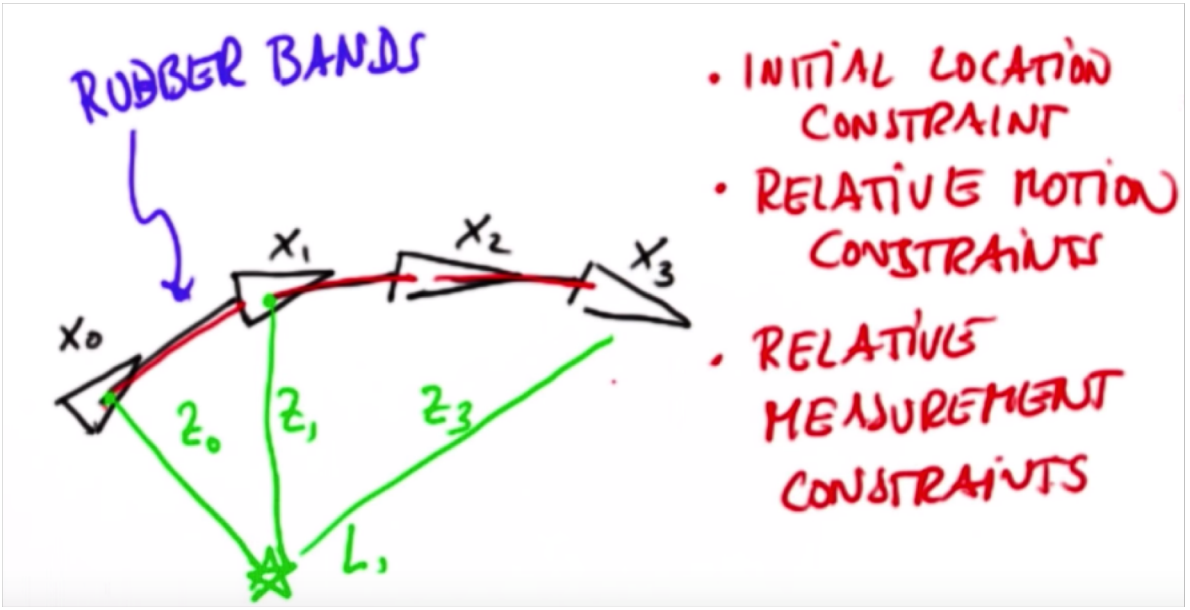
- **Key Idea:** Constraints and Relaxation
  - "Just make it work"
- **Initial Pose**
- **Move**
  - Uncertainty
  - Model as Gaussian



Graph SLAM

- **Constraints:**
  - Initial Location Constraint
  - Relative Motion Constraint
  - Relative Measurement Constraints

- **Constraints are like "rubber bands"**
- **Find the best combination**



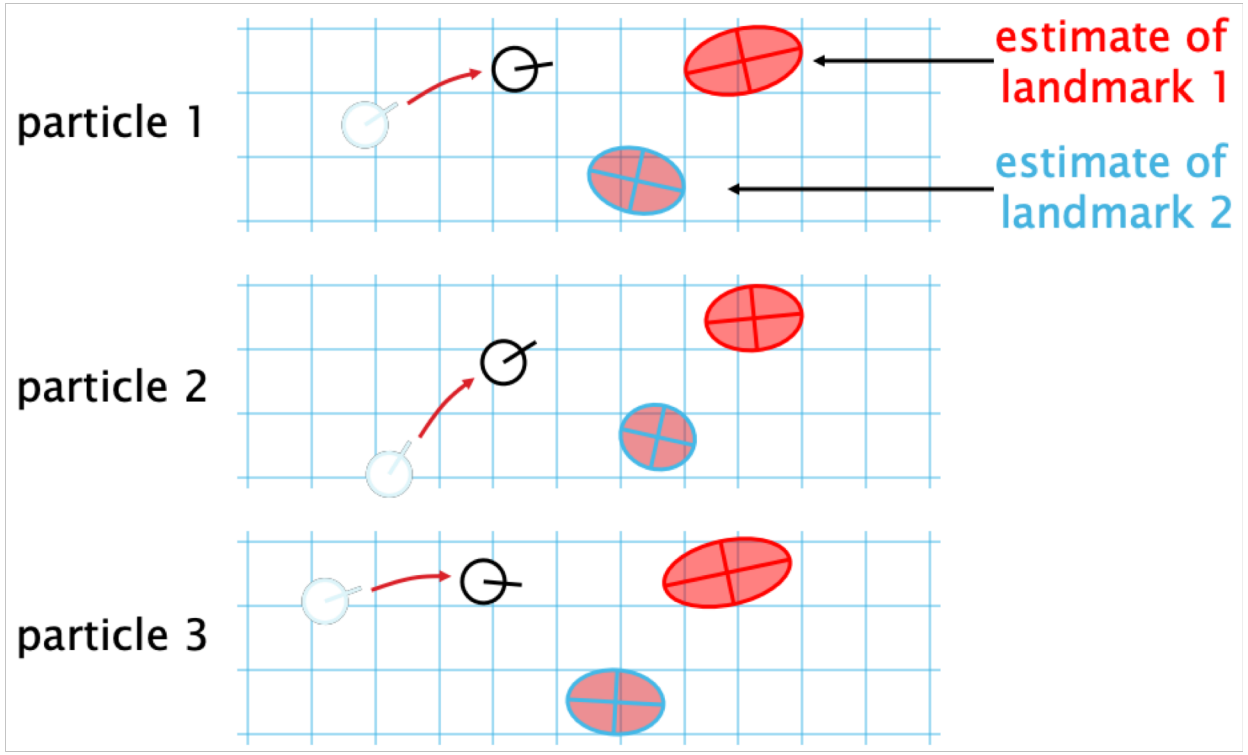
FastSLAM

- Use the same idea as a **particle filter**
- But...
  - We don't know which measurement corresponds to which landmark (could be unseen or seen landmarks)
  - Uncertainty in pose

- **Key insight:** Landmarks are independent of each other given all poses, correspondences and measurements

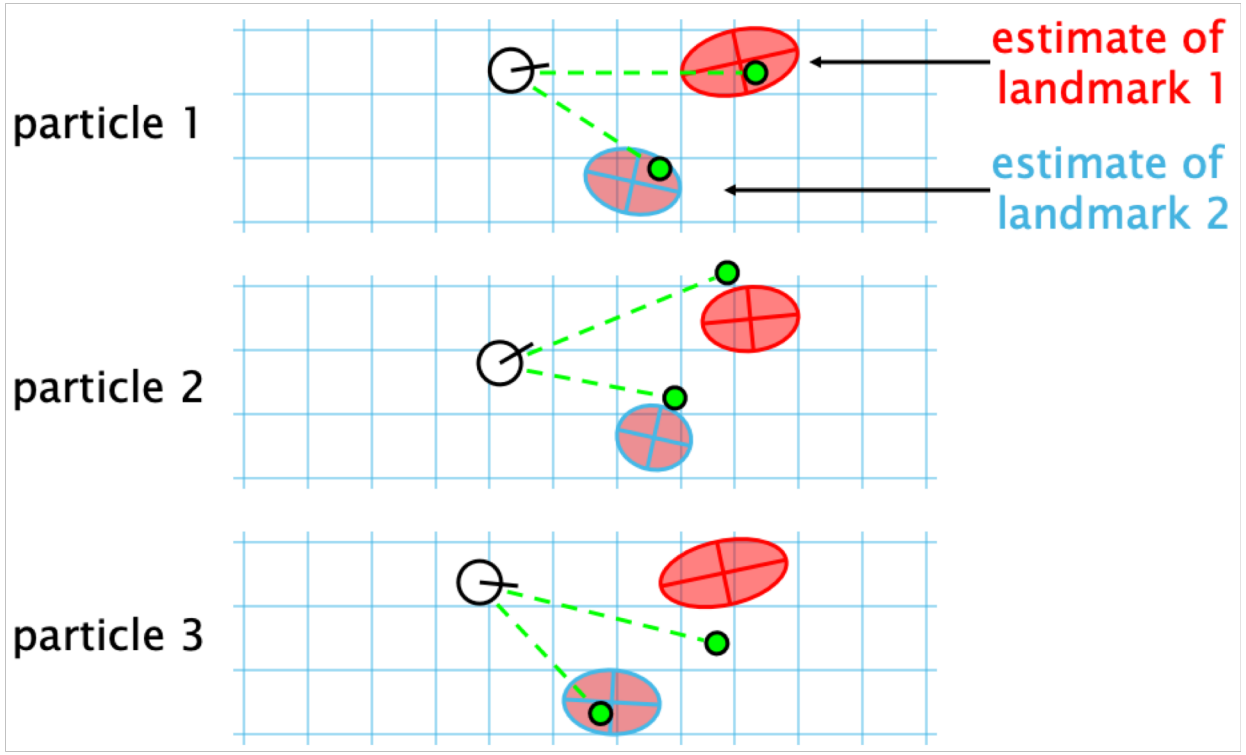
FastSLAM

1. Motion Update



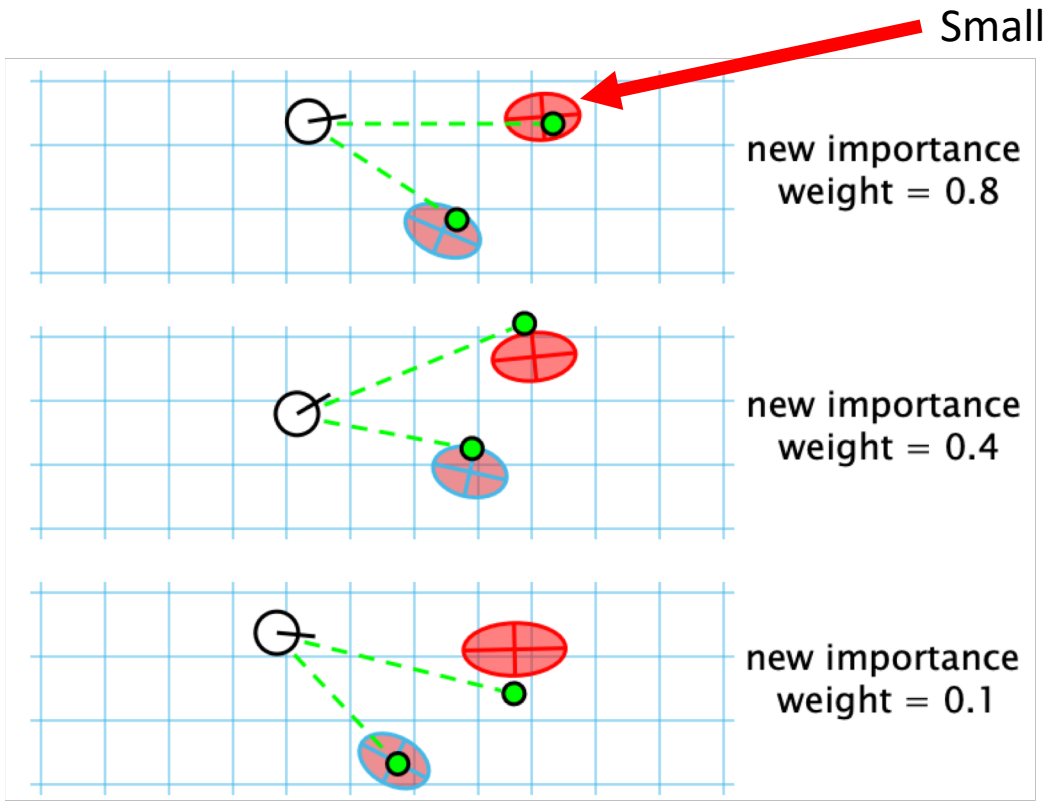
FastSLAM

2. Measurement Update



FastSLAM

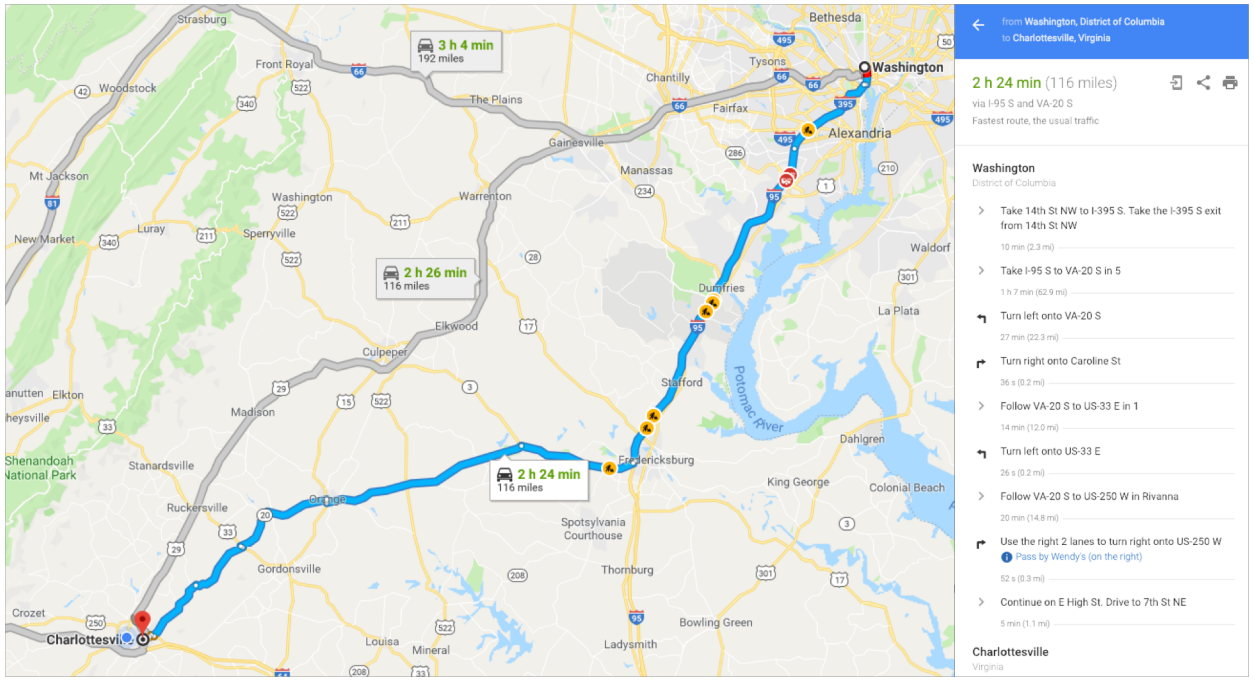
3. Importance Weights and Map Update

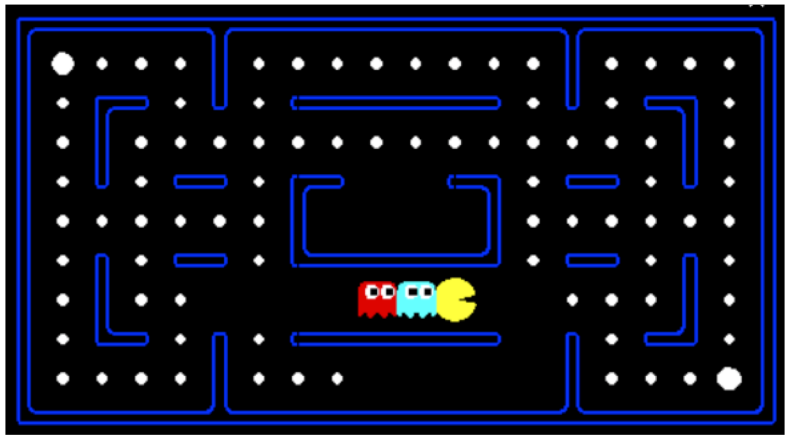


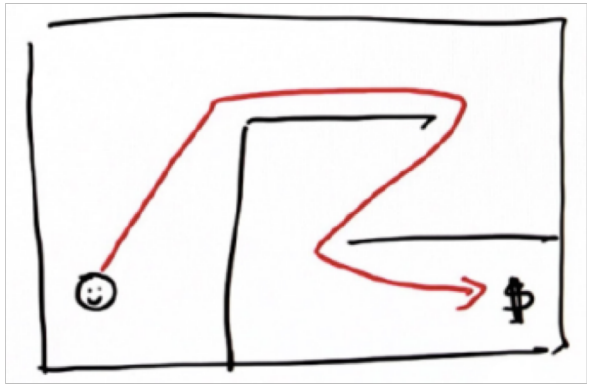
4. Resample

What is Motion Planning?

Ultimate Goal: Autonomously get from **point A** to **point B**







What is Motion Planning?

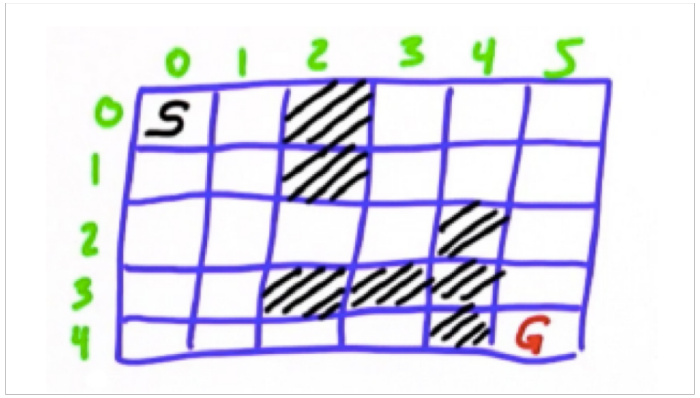
General – AI Search Problem:

- Determine sequence of actions to get from one configuration to another

Special – Robot Motion Planning Problem:

- Get from *location* A to *location* B on a map

- **Given:**
  - Map
  - Start Location
  - End Location (Goal)
  - Cost
- **Find:**
  - Minimum-cost path



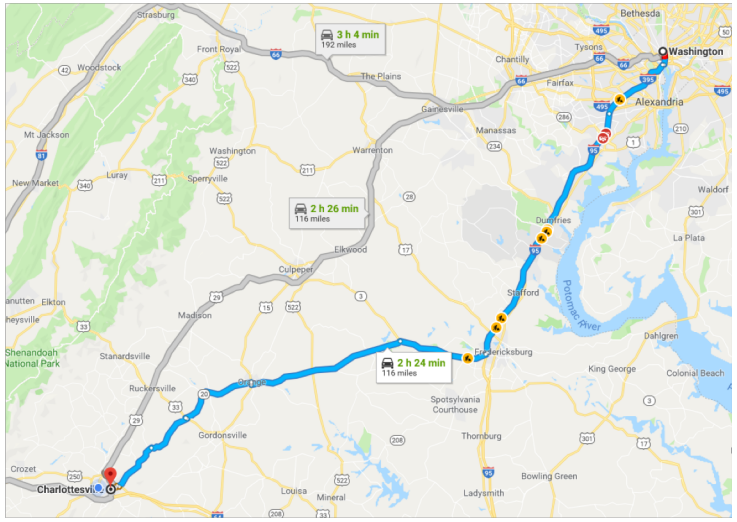
Global vs Local Motion Planning

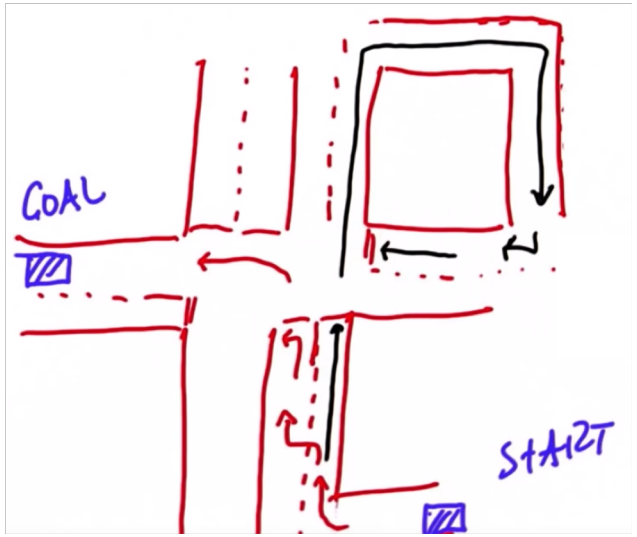
Global:

- High-level Graph Search
- Obstacle Avoidance

Local:

- Lane changes
- Turns
  - Protected vs Unprotected
  - Right vs Left
- Occlusions
- Speeds
- Prediction of other actors





Waymo Cars Have a Hard Time Making Left Turns – Johnathan ...
https://medium.com/.../waymo-cars-have-a-hard-time-making-left-turns-d21cb438c01...
Aug 28, 2018 - The **Waymo** vans have trouble with many unprotected **left turns** and with merging into heavy traffic in the Phoenix area, especially on highways.

Waymo's left turns frustrate other drivers | Brad Ideas
https://ideas.4brad.com/waymos-left-turns-frustrate-other-drivers
Aug 29, 2018 - A lot of the problems involve over-hesitation at an unprotected **left turn** near the **Waymo** HQ. The car is just not certain when it can turn. There is ...

Waymo's self-driving cars 'struggle to turn left and don't understand ...
https://www.telegraph.co.uk › Technology Intelligence
Aug 29, 2018 - Self-driving cars designed by **Waymo**, a subsidiary of Google's parent company, Alphabet, have problems understanding the basic rules of the road, according to a new report. ... The cars reportedly have difficulty turning **left** on fast-moving roads and have a habit of stopping at traffic ...

Waymo Will Never Be Able To Make ALL Left Turns : SelfDrivingCars ...
https://www.reddit.com/r/.../waymo_will_never_be_able_to_make_all_left_turns/
Dec 19, 2018 - Morning rush hour yesterday I was trying to **turn left** onto a two-lane ... Closing **Waymo** won't sink the ship, but it will send a clear message to ...

Even self-driving leader Waymo is struggling to reach full autonomy ...
https://arstechnica.com/.../waymos-lame-public-driverless-launch-not-driverless-and-b...
Dec 7, 2018 - According to The Information's Efrati, **Waymo** has struggled with turning from a low-speed residential street onto a major boulevard. This is also a problem The Washington Post observed during a recent **Waymo** test ride. The Post reported that "**left turns** can be painfully slow" when turning onto a major traffic artery.

Left turns are hard for self-driving cars and people alike | Popular ...
https://www.popsci.com/self-driving-cars-unprotected-left-turns
4 days ago - **Waymo** racks up 10 million miles in simulation daily, according to the company. **Waymo** started using simulation years ago to answer a question about disengagements—the industry term for when the human in a self-driving car takes over the controls from the autonomous software.

Cost Functions

What are Cost Functions?

- Whatever we want to minimize
- E.g. Time, Money (toll/gas), Distance (shortest path), etc...
- Usually interested in "shortest paths"

Scenario A:

- Move cost = 1
- Turn cost = 1

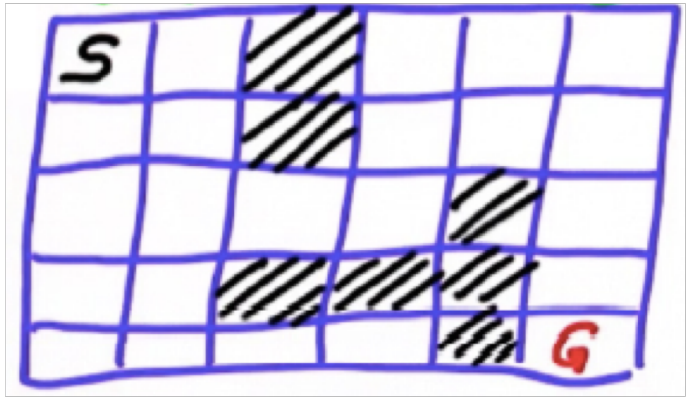
Scenario B:

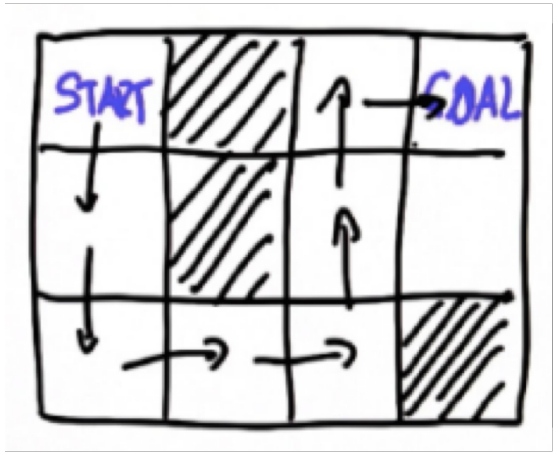
- Move forward cost = 1
- Move right cost = 1
- Move left cost = 10
  - *What if "move left cost = 12"?*

Grid Search

Representation Matters!

- Let's model our problem as a grid search problem...

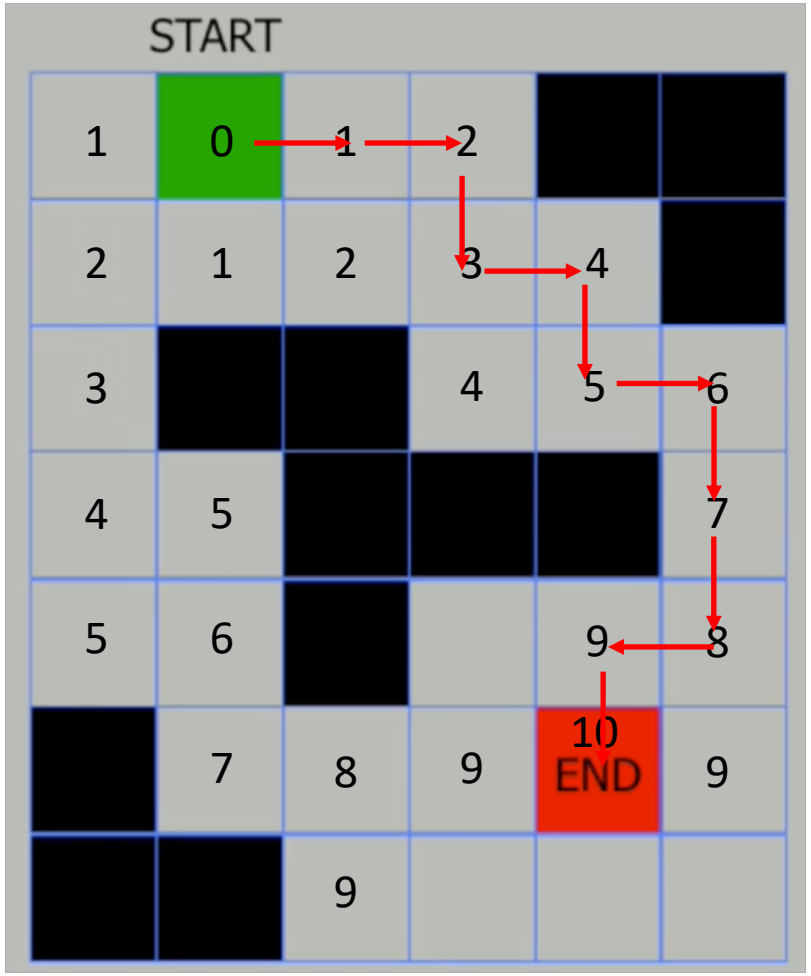




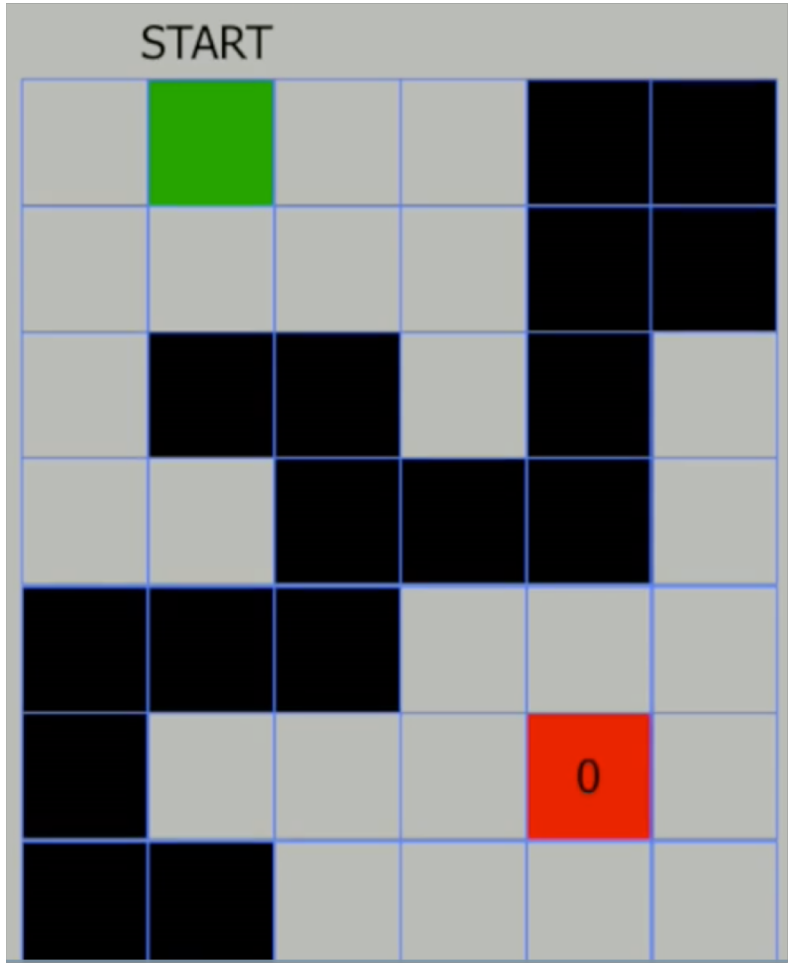
How would a computer do it?

- Think about a procedural way to get from one cell to the next...
- Hint: Keep a list of unvisited items!

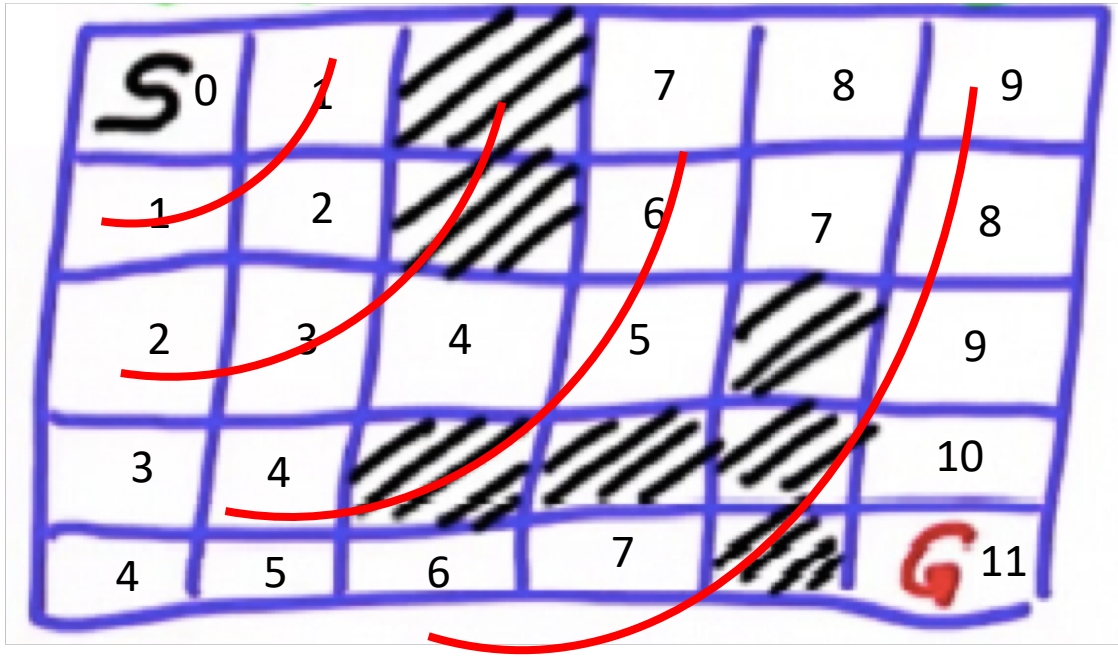
Grassfire Algorithm



Grassfire Algorithm



Grassfire Algorithm



Grassfire Algorithm

Key idea: keep track of the order in which the "fringe" cells expand

How?

- Maintain a dynamic list ("queue") of unvisited cells

Pseudo-code:

```
For each node n in the graph
    n.distance = infinity

Create an empty list
Set goal.distance = 0 and add goal to list

While list is not empty
    Let current = first node in list, remove current from list
    For each node n that is adjacent to current
        If n.distance = infinity
            n.distance = current.distance + 1
            Add n to back of the list
```

Grassfire Algorithm

Pros:

- If path exists between start and goal, it will find the *shortest path*
- If no path exists, it will discover this
- Simple and easy to program

Cons:

- Computationally inefficient
  - Storing too much!
  - Computation effort increases *linearly* with number of cells
  - **Do we need to explore all possible fringes? Or are there better ones...**