Robot Navigation (Mapping, Exploration)

Robots Navigation

- Path Planning: How to I get to my Goal?
- Localization: Where am I?
- Mapping: Where have I been?
- Exploration: Where haven’t I been?

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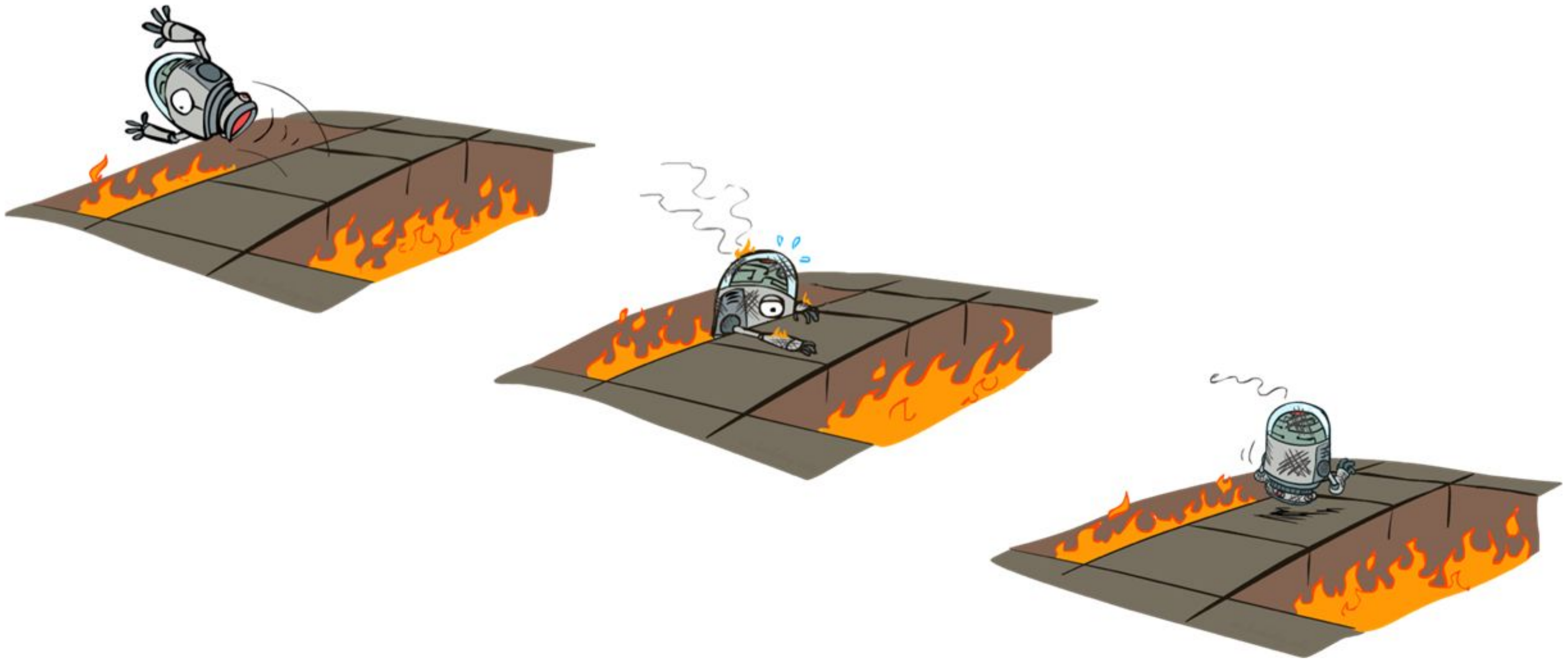
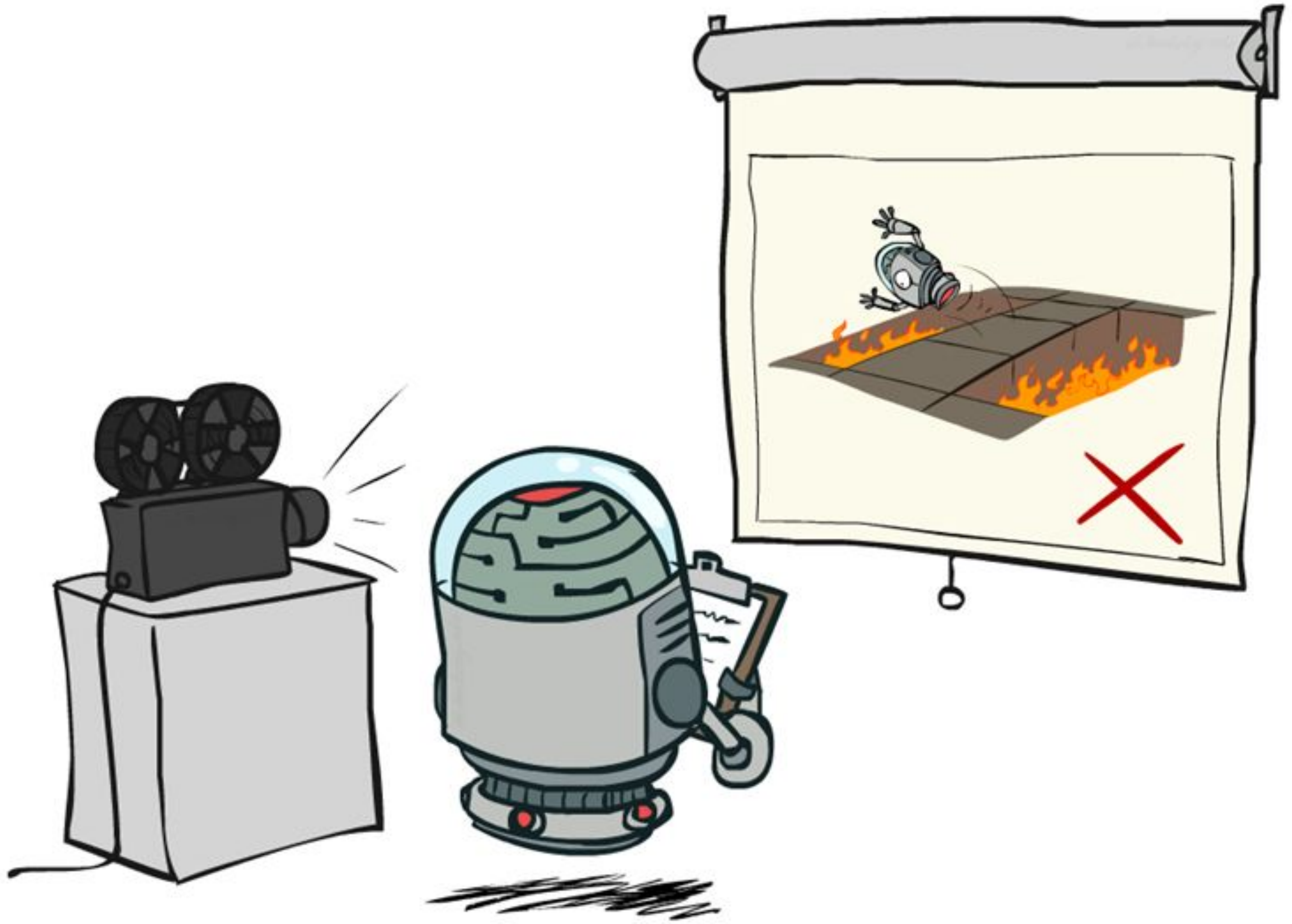


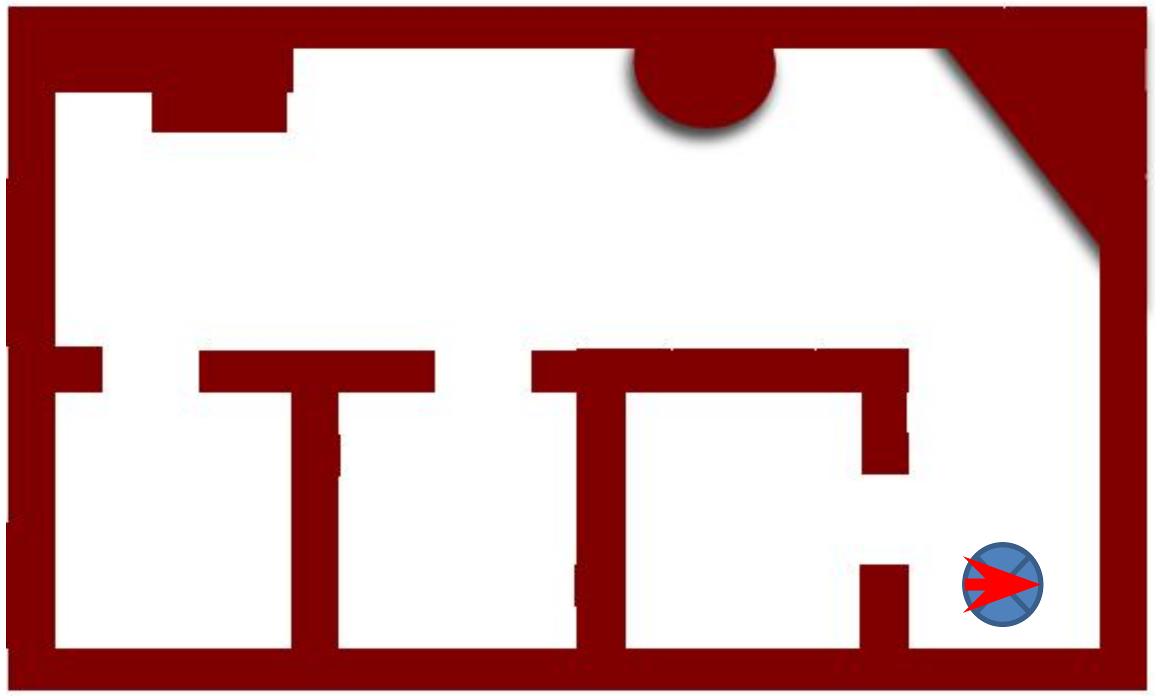


Mapping and Exploration

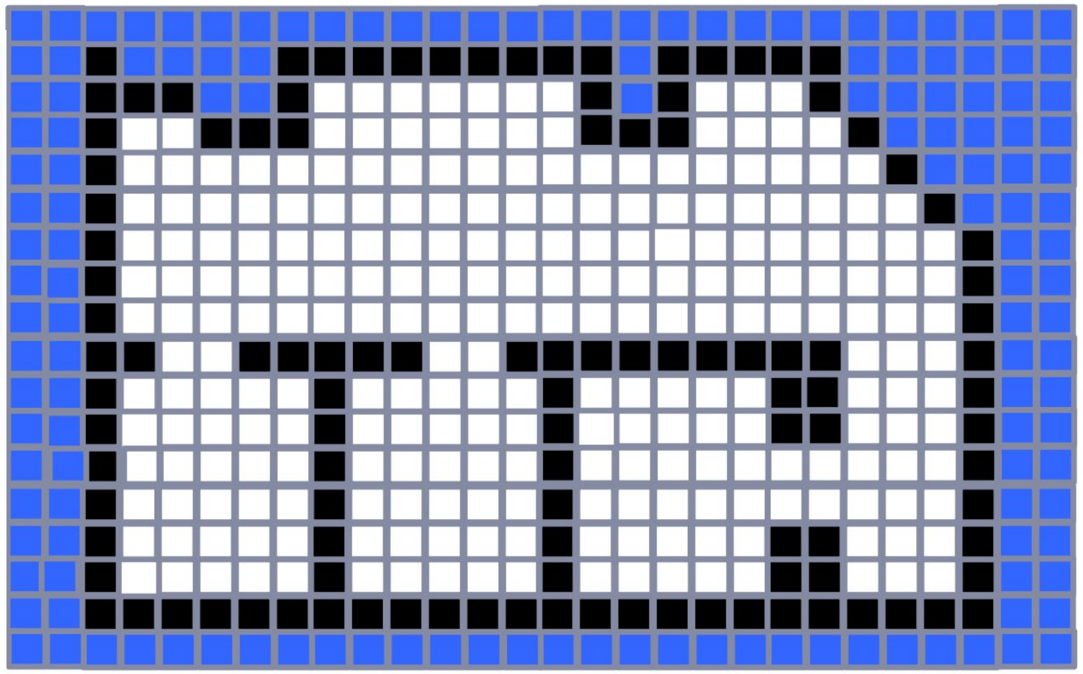
- **Question:**
  - You are roaming around in an unknown space, what can you learn about it?
- Two parts of the problem:
  - Mapping: As you roam around the world, how do you build a memory of the shape of the space you have moved through?
  - Exploration: Given that you don’t know the shape or size of the environment, how to make sure you covered all of it?
- Mapping and Exploration are also “collections of algorithms”
  - We will focus on “Occupancy Grid” algorithms

What is an Occupancy Grid?

- A way of representing a map as a gridded world where each cell is either “occupied” or “empty” or “unknown”.

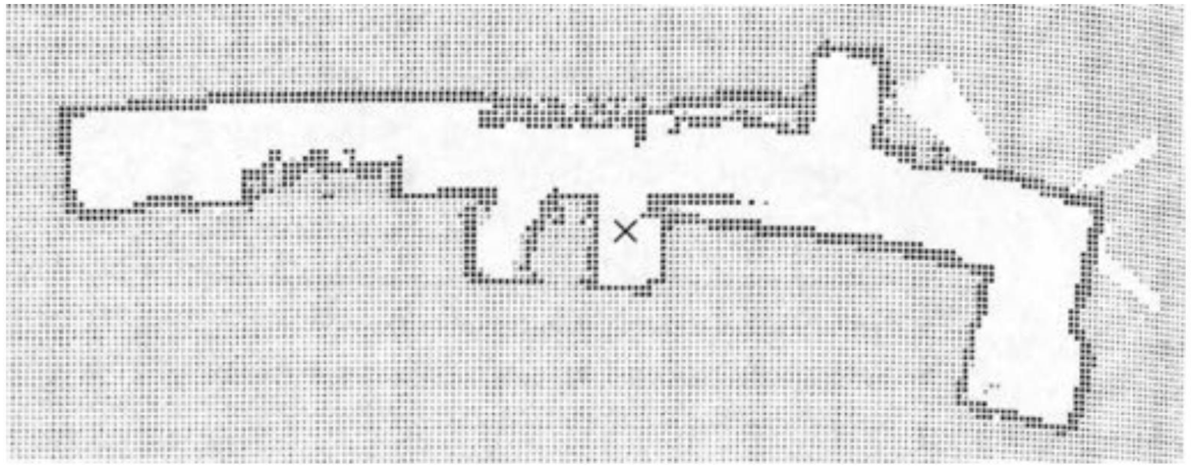


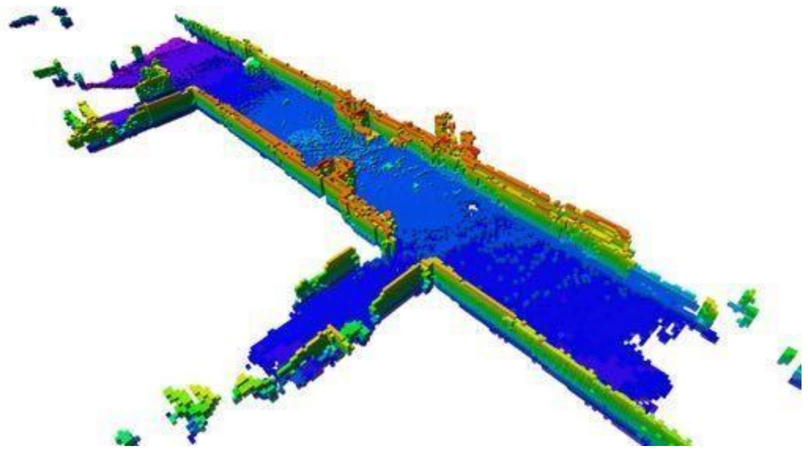
Your World

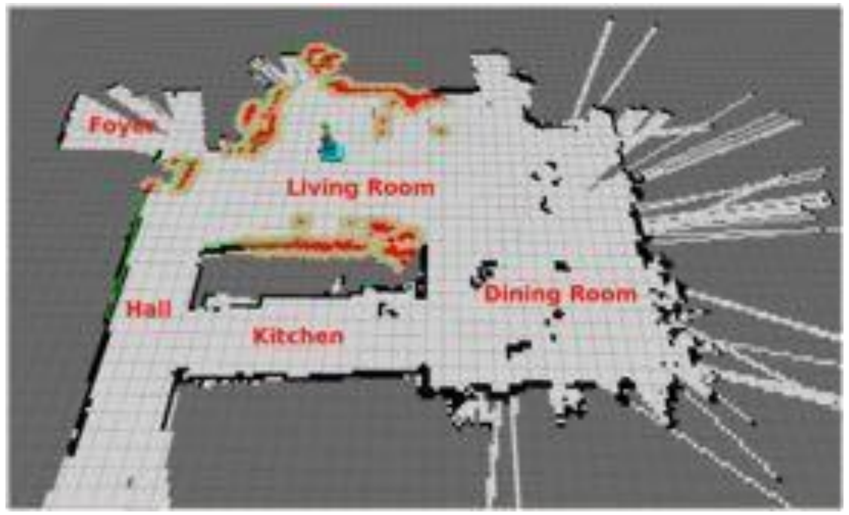


Grid generated by a Robot => boundary shape

Examples







What is a Sensor Model?

- Constructing a Sensor Model
  - A sensor measures *raw values* in an environment
  - You have to map that into a Grid Cell Value.
  - Robots can have very different sensors and configurations
  - Examples:
    LIDAR/Depth Camera
    Vs. a 360 degree vision/ranging system

Constructing a Sensor Model

- **Example: Depth Sensor Model**

  R = maximum range, B = maximum angle

  Let say the sensor at point p returns **distance = “r”**

  Region 1 (dist < r, grid cell probably empty)
  Region 2 (dist = r, grid cell probably obstacle)
  Region 3 (dist > r, grid cell unknown/obscured)

- Simplest Sensor Model

  Where I stand is Empty (white)

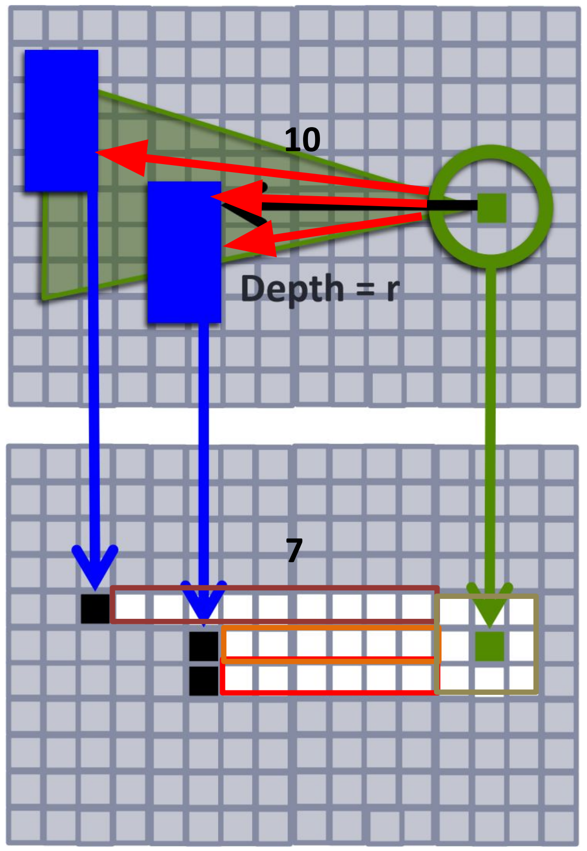
- A Better Model

  Set Region 1 cells as Empty (white)

  Set Region 2 cells as Occupied (black).

  Pick a max range/angle where data is reliable

  Rest is still Unknown (gray)



A Simple OG Mapping Algorithm

1. Initialize a Grid
   - Set all locations as “unknown”, pick a start location and orientation
2. Update the Grid
   - *Mark your current grid position as “empty”*
   - Using your better sensor model,
   - *Mark all visible grid locations as “empty” or “occupied”*
3. Pick a Next Move
   - Look at neighboring grid positions in your map
   - Pick a neighboring grid location that is empty (randomly)
   - Move to it and update your current position in the Grid
4. Loop forever
   - Keep moving and updating the grid (unless you are “done”)

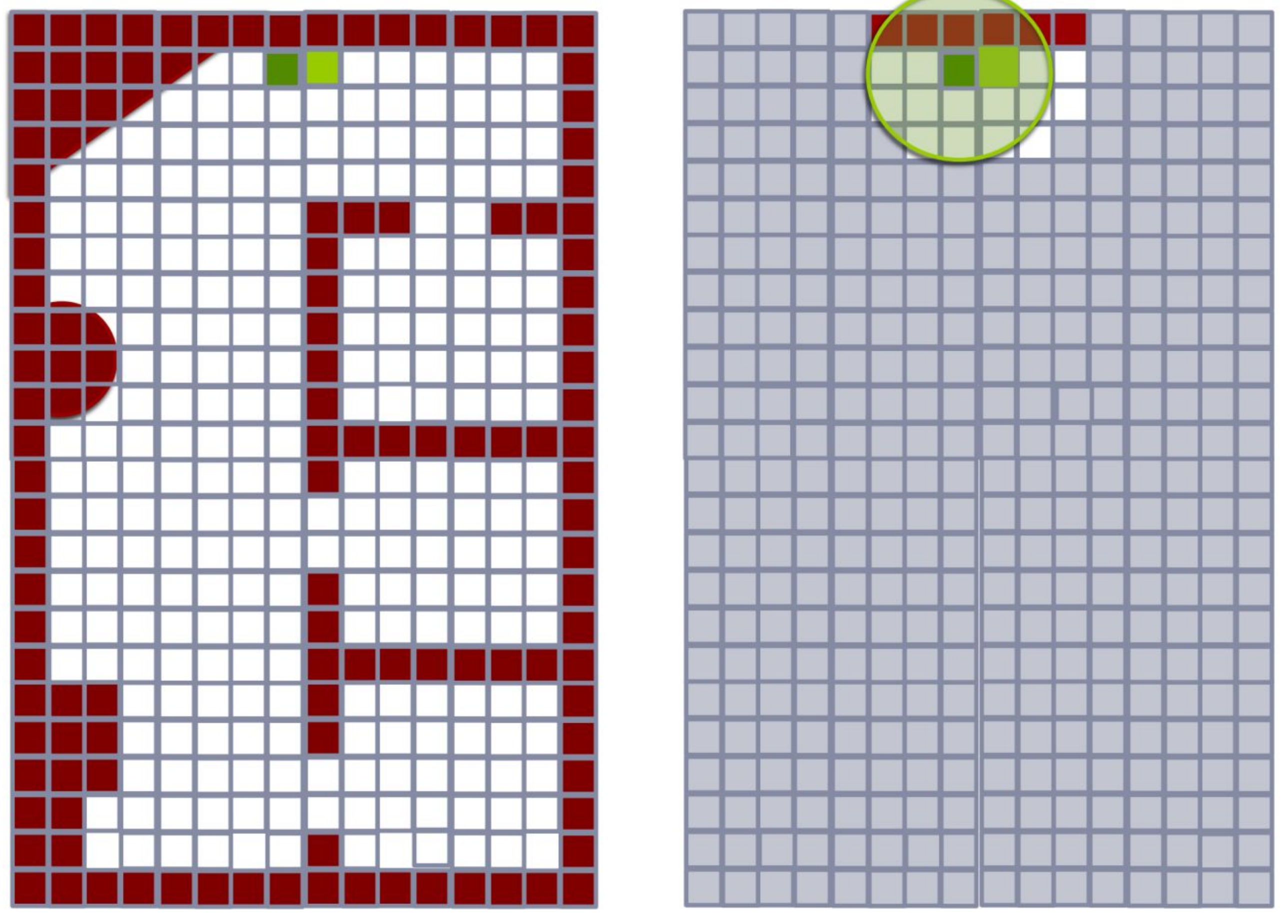
Exploration

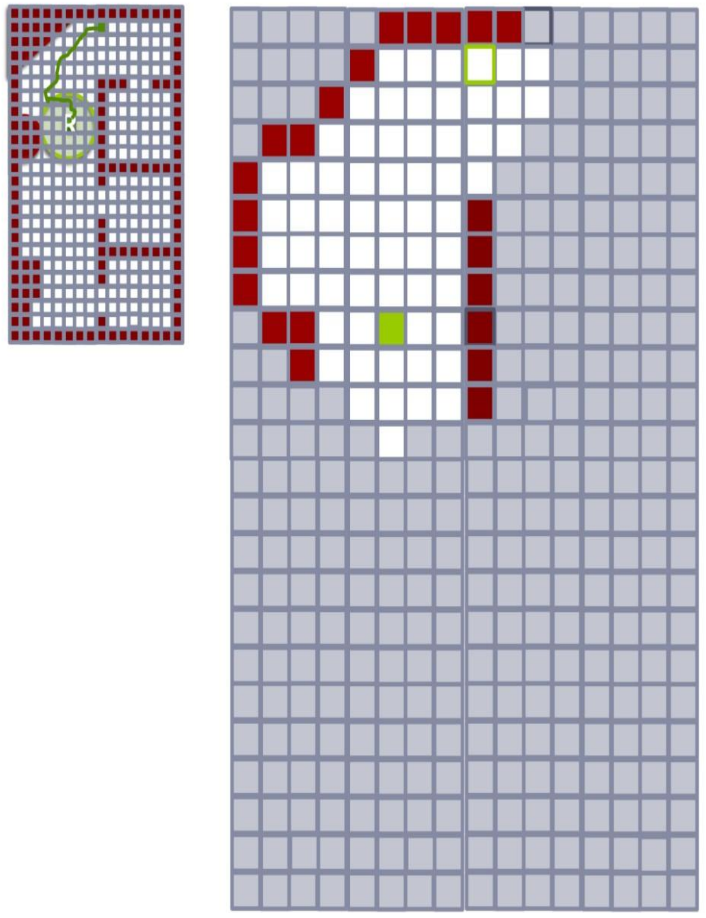
- Basic Concept in Robotics: Navigating a GRID Graph is different
  - DFS works, but will still make a robot retrace steps
  - **Better choice: Frontier Based Exploration**

Exploration in Grid Worlds

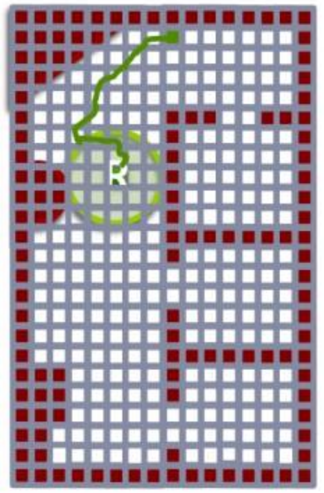
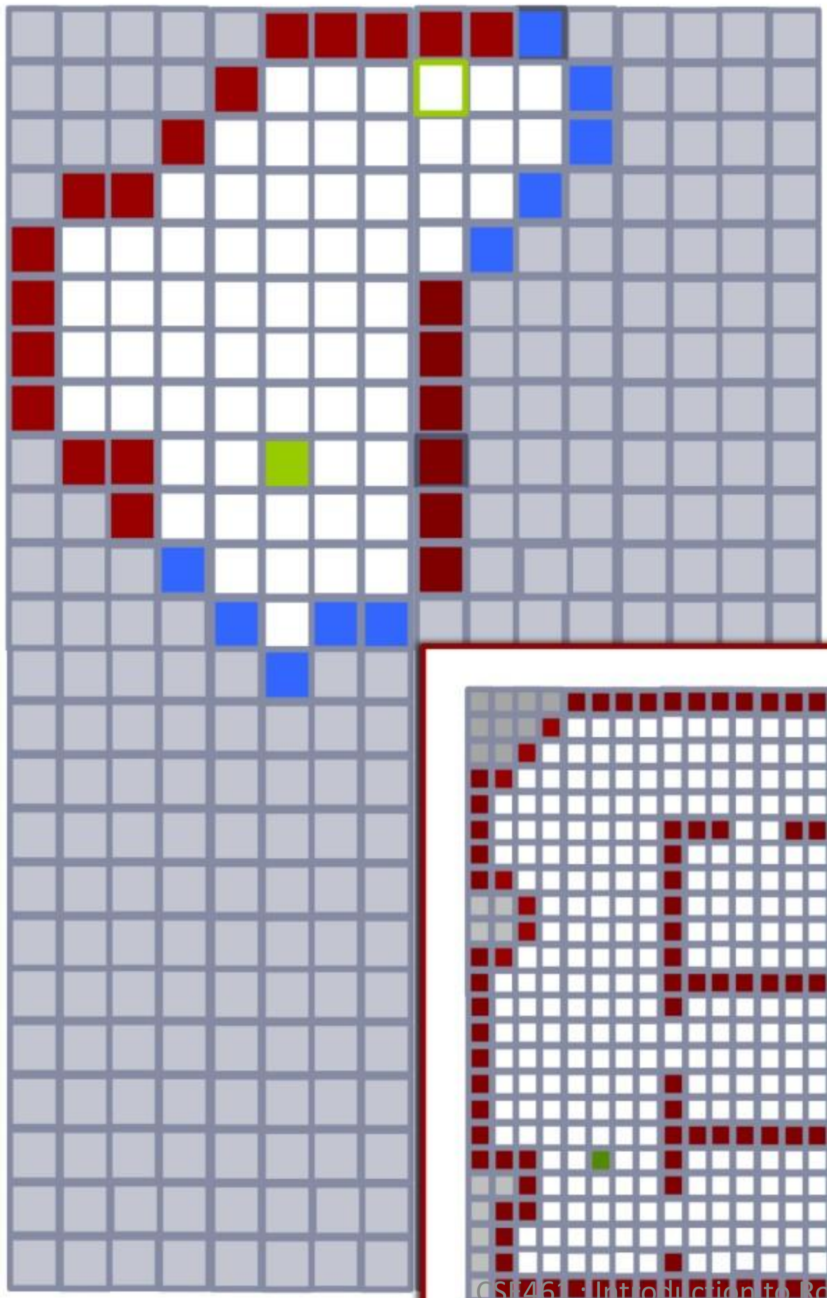
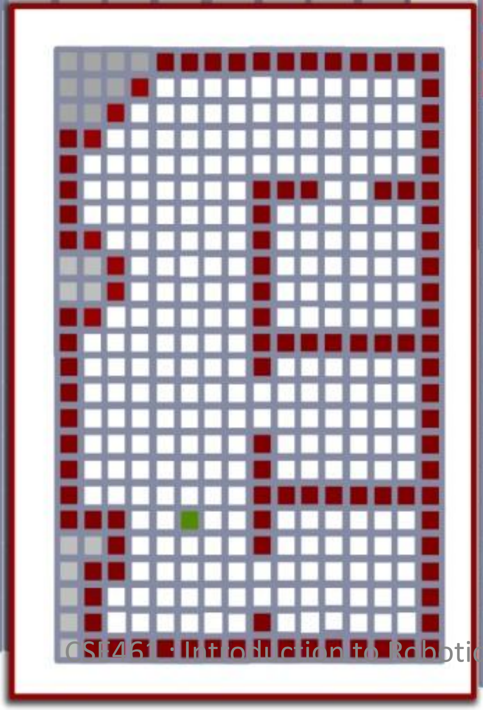
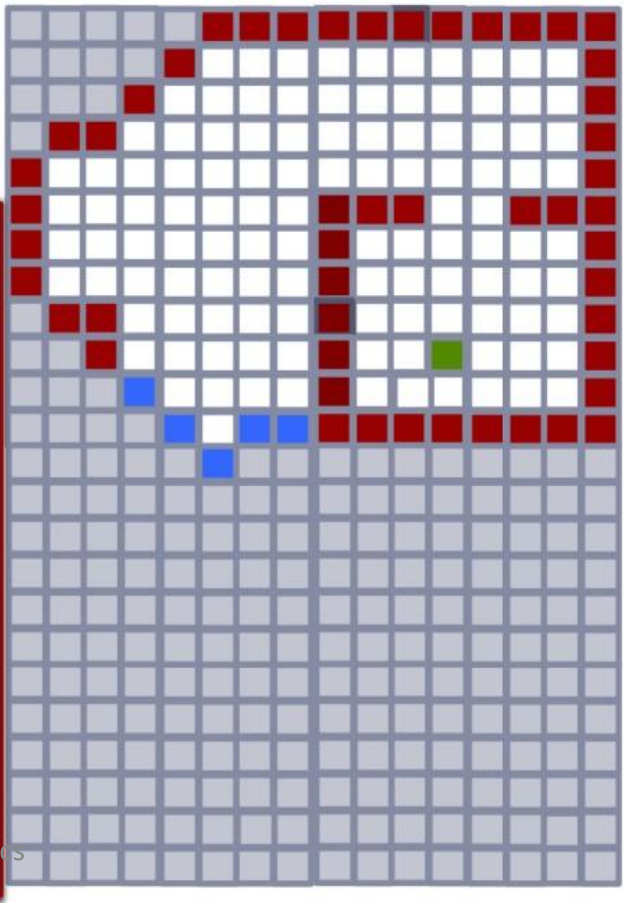
- **Frontier Based Exploration**
  - A common technique for building maps
  - Key Idea:
    - Identify the “frontiers” between known and unknown
      Frontier cell = a unknown cell with at least one empty cell
    - Pick a frontier cell (e.g. the closest)
      Plan a path to go explore it.
  - Done Condition:
    No more frontier nodes left => your map is Complete!
    If finite world, then any algorithm that systematically explores frontier nodes is guaranteed to cover the whole world.

Frontier Based Exploration





A Frontier Node is a
Gray node (Unknown)
next to a
White node (Empty)

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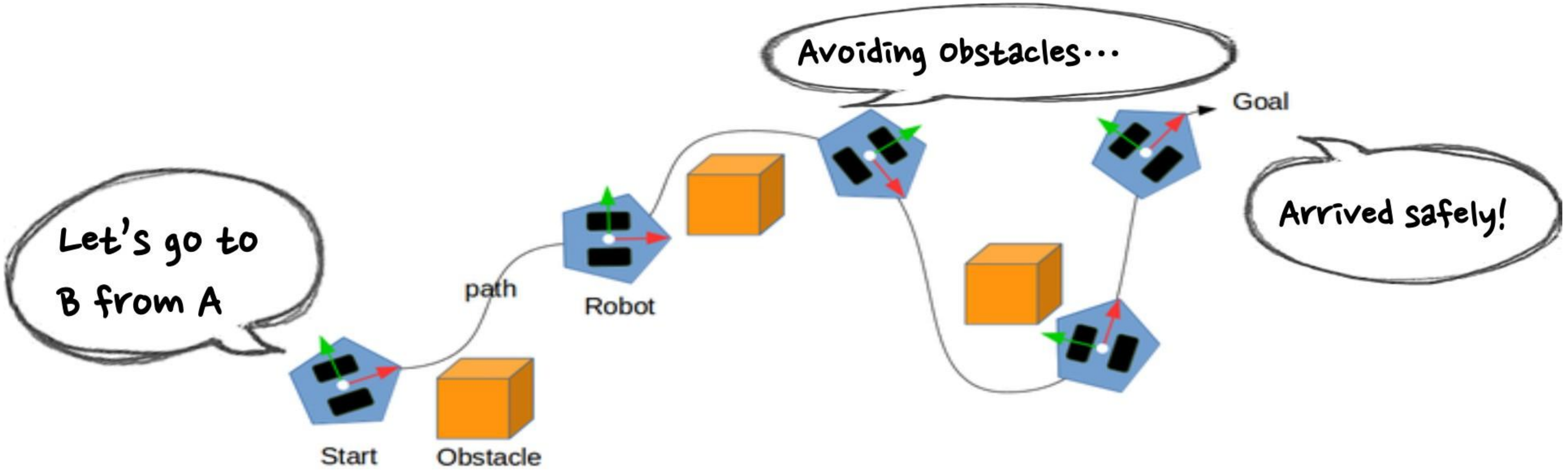
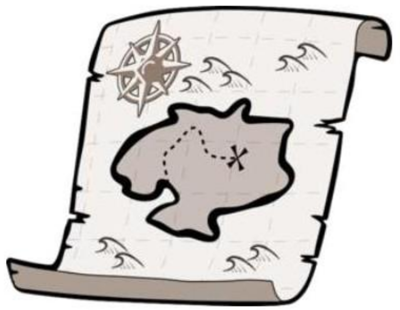
Summary



① **Position**: Measuring/estimating the robot's position
② **Sensing**: Measuring obstacles such as walls and objects
③ **Map**: Maps with road and obstacle information
④ **Path**: Calculate optimal path to the destination and follow the path

Summary

① **Position** ② **Sensing** ③ **Map** ④ **Path**



Position + Sensing → **Map**

SLAM

Simultaneous Localization And Mapping

Position + Sensing + Map → **Path**

Navigation

Thank You