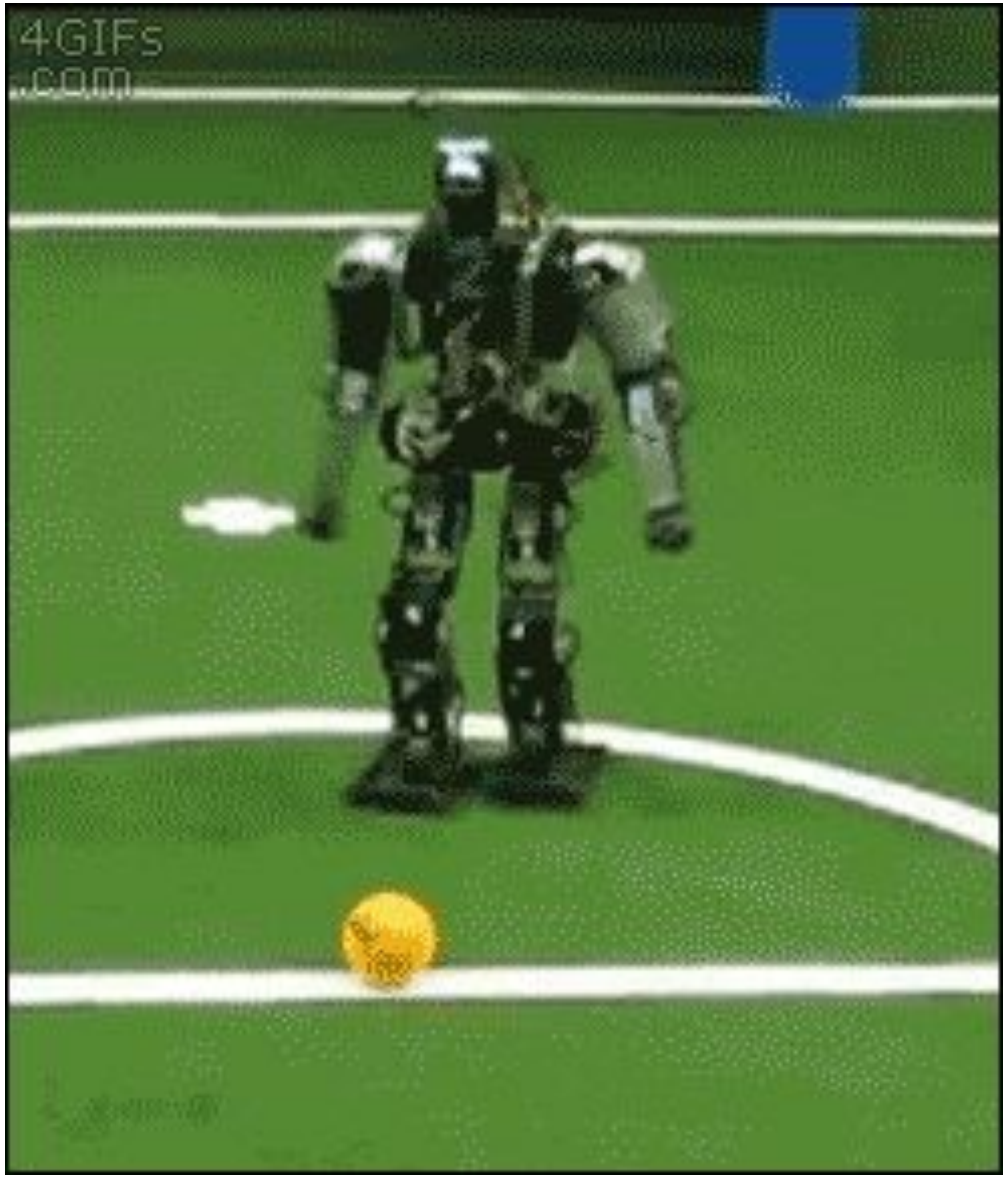
Robot Navigation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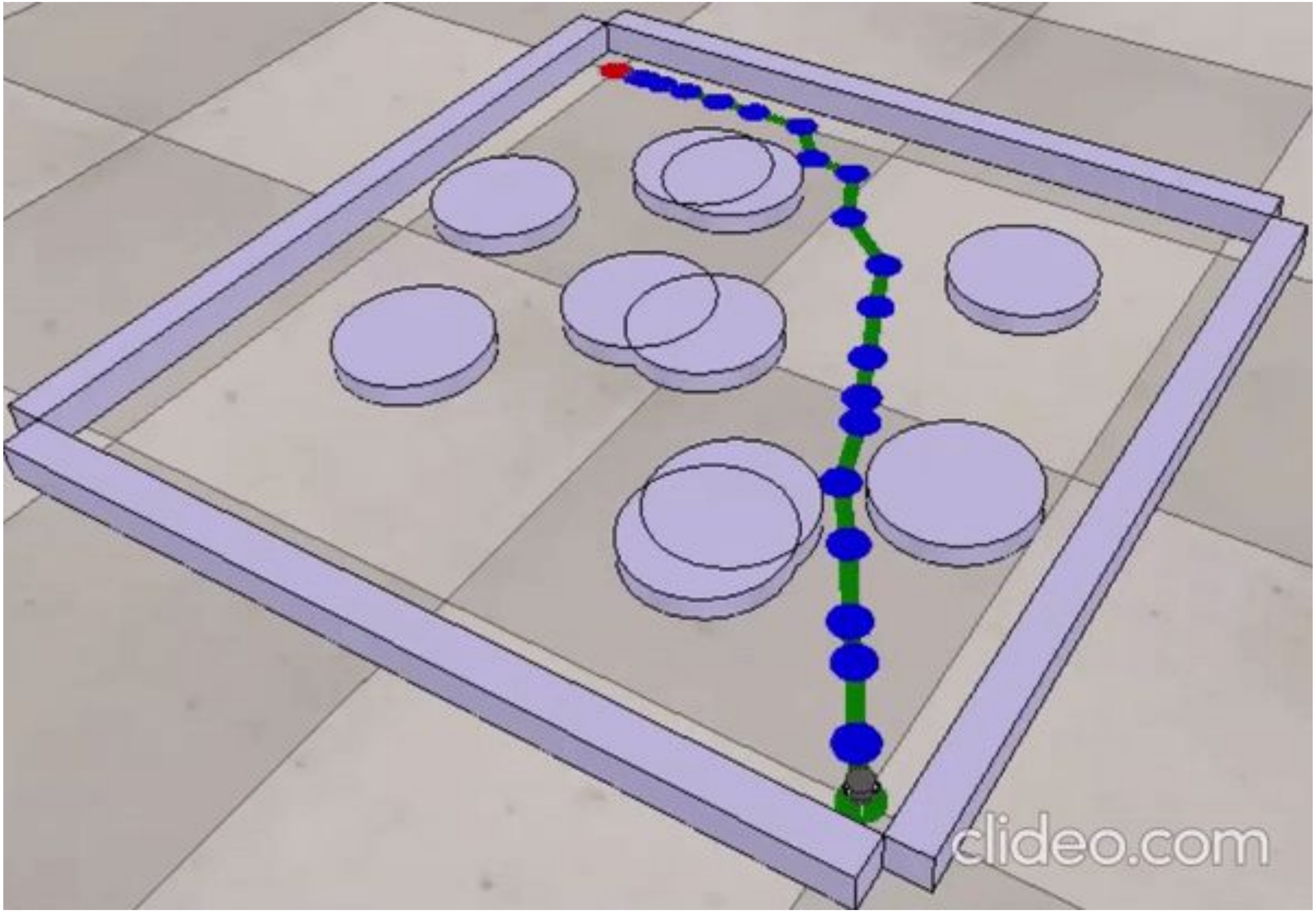
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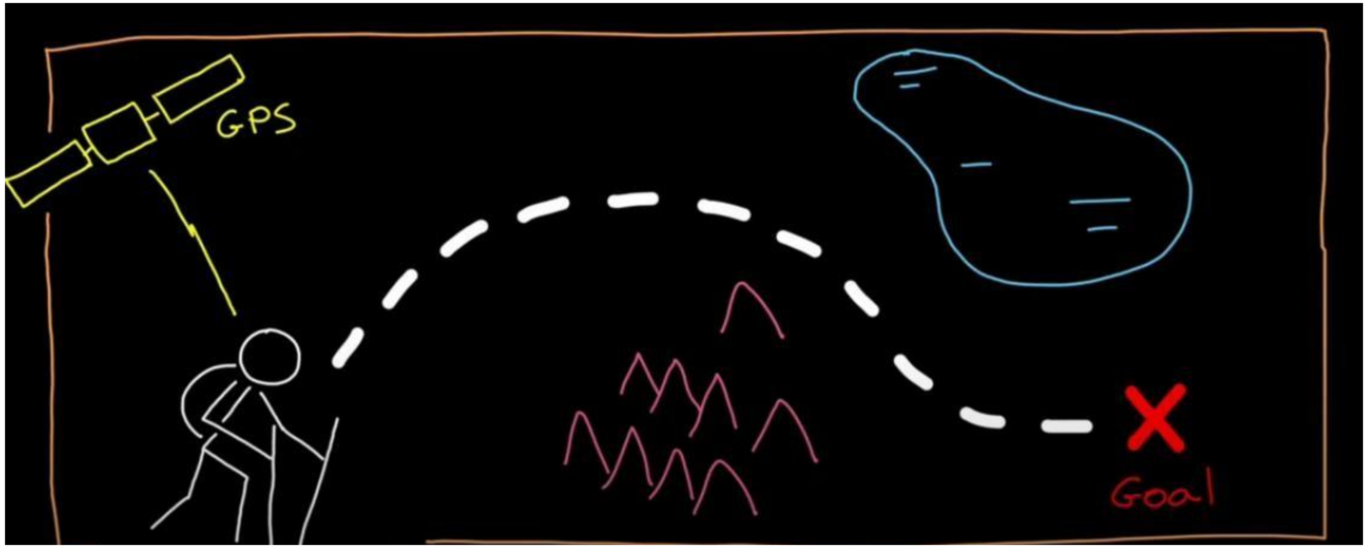
Navigation

- The act, activity, or process of finding the way to get to a place
- Navigation is the ability to determine your location and plan a path to some goal



Robot Navigation

For autonomous behavior, robots need the ability to navigate:

- Learn the environment->“Model”
- Estimate where it is in the environment->“Localize”
- Move to desired locations in the environment

Navigation Example

Scenarios

- Hospital Helper

(e.g. Diligent, Tugs)

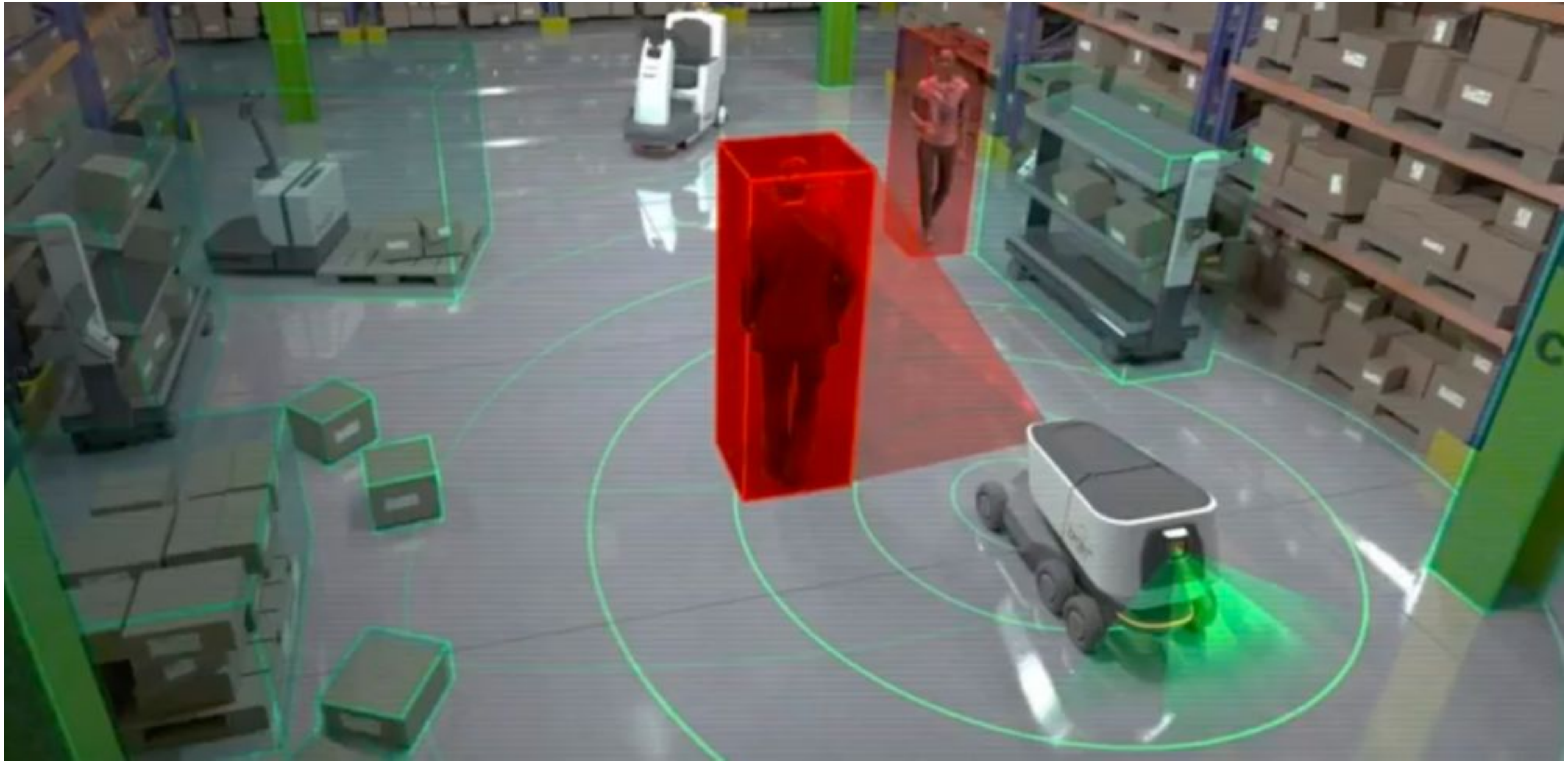
- Office security or mail-delivery

(e.g.Cobal, Savioke)

- Tour Guide robot in a museum (Minerva)
- Autonomous Car with GPS and Nav system

Biological analogies:
Humans, bees and ants, migrating birds, herds

Environment



Navigation Problem

Problem Characteristics

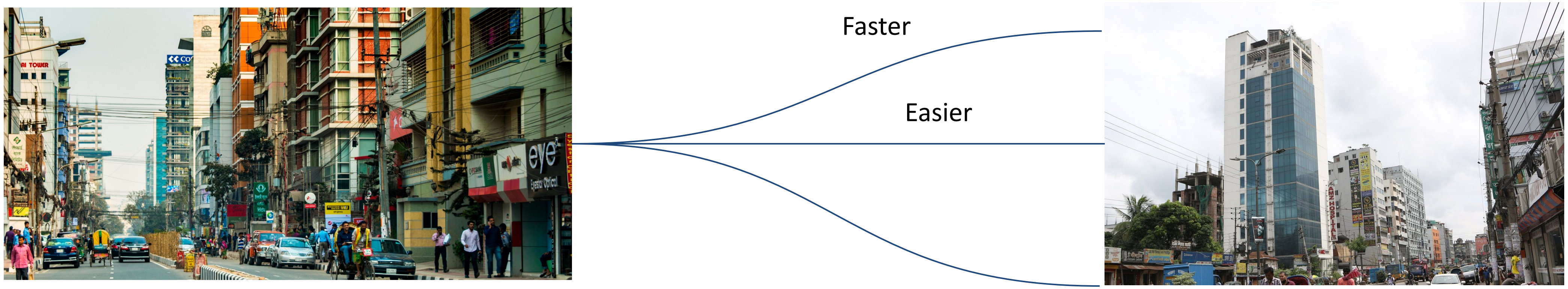
- Environments are Known versus Unknown
- Environments are Static versus Dynamic
- Environments are Structured versus Unstructured (Indoors versus Outdoors?)

We have to design the navigation system

Robots Navigating

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

What is Path Planning?



Banani

Energy
Efficient

Badda

What is Path Planning?

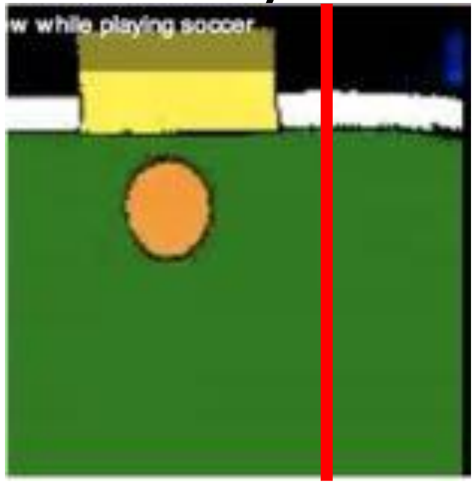
- Simple Question: How do I get to my Goal?
- Not a simple answer!
  - Can you see your goal?
    - Do you have a map?
    - Are obstacles unknown or dynamic?
  - Does it matter how fast you get there?
  - Does it matter how smooth the path is ?
  - How much compute power do you have?
- Path Planning is best thought of as a Collection of Algorithms

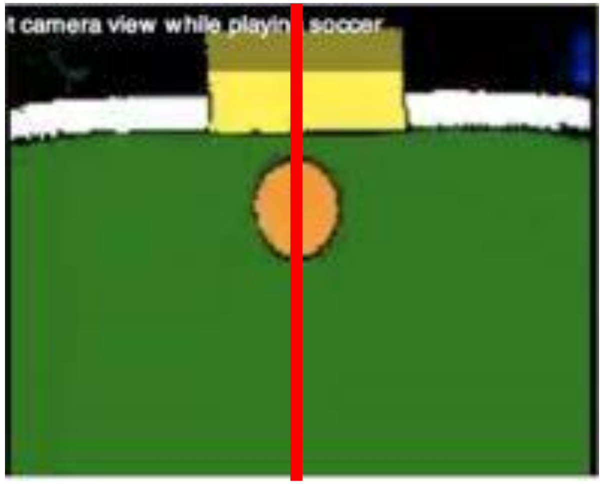
We know our criterias now what?

Basics: Visual Homing

Purely Reactive Navigation

- Measure Visual (x,y) Position of Goal
- Move to bring goal to Visual Center
- Proportional Control (if you see the goal), Random walk (if you don't)

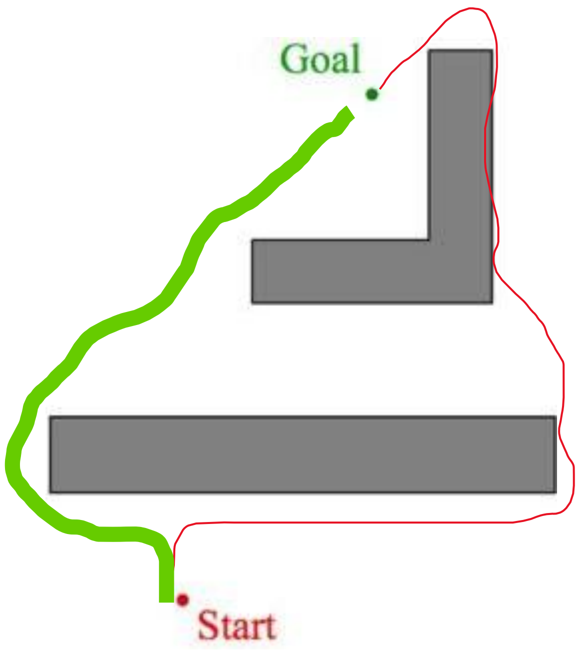




Bug-based Path Planning

- What if the Robot has obstacles in the way?
  - Always have Goal direction and/or distance (Global)
  - But No Map: Only local knowledge of environment (Local)

- Very intuitive class of algorithms – but surprisingly powerful

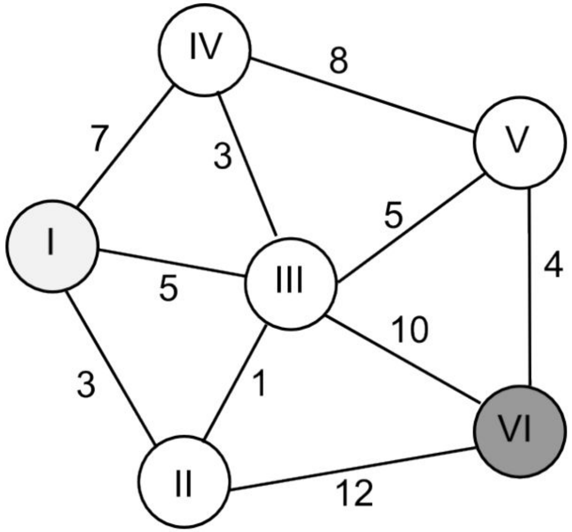


If Map is given ?

Map Representation: Feature based

Path Finding Algorithms

- All Map Representations are a weighted “graph”
  - Nice part is that you only need to do this once
- Algorithm: Compute shortest paths in the graph
  - Path is represented by a series of waypoints



Metric/Global Path Planning

- What if the Robot has Full Knowledge
  - A map of the environment and robot + goal's locations
  - Goal: Find a "optimal" path (typically distance)

- Two Components
  - Map Representation ("graph")
  - Path Finding Algorithms:
    - Shortest-Path Graph Algorithms (Breadth-First-Search, A* Algorithm)

Types of Path Planning Approaches

- Basics
  - Visual homing (Purely local sensing and feedback control)
- Bug-based Path Planning (mostly-local without a map)
- Metric (A*) Path Planning (global with a map)

Robots Navigating

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

Localization

- **Simple Question:** *Where am I?*
- **Not a simple answer:**
    - Do you have a map?

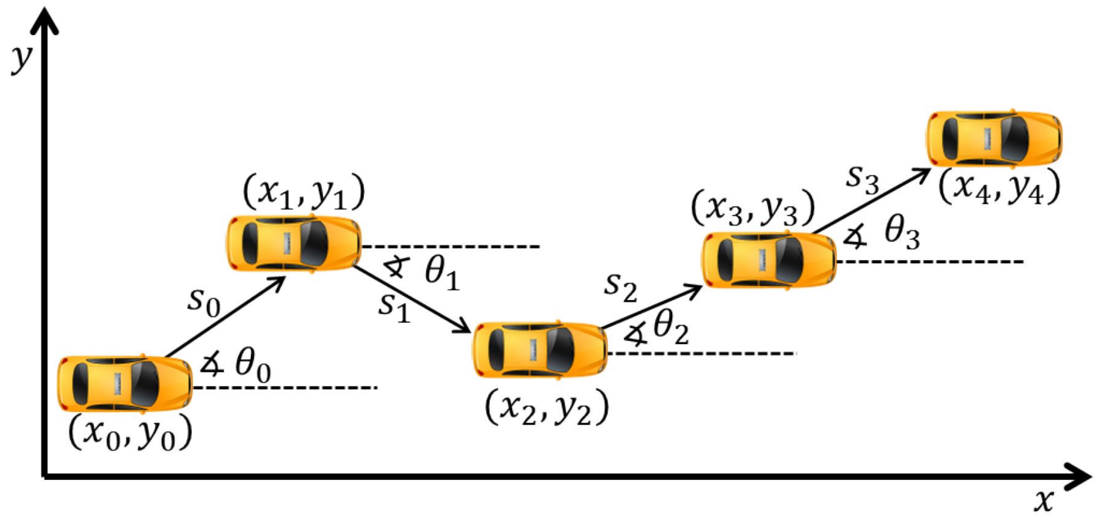
      Yes => a global position in the world

      No => position in reference to other objects? Or your own past?
    - What can you sense?

- **Localization is a “collection of algorithms”**

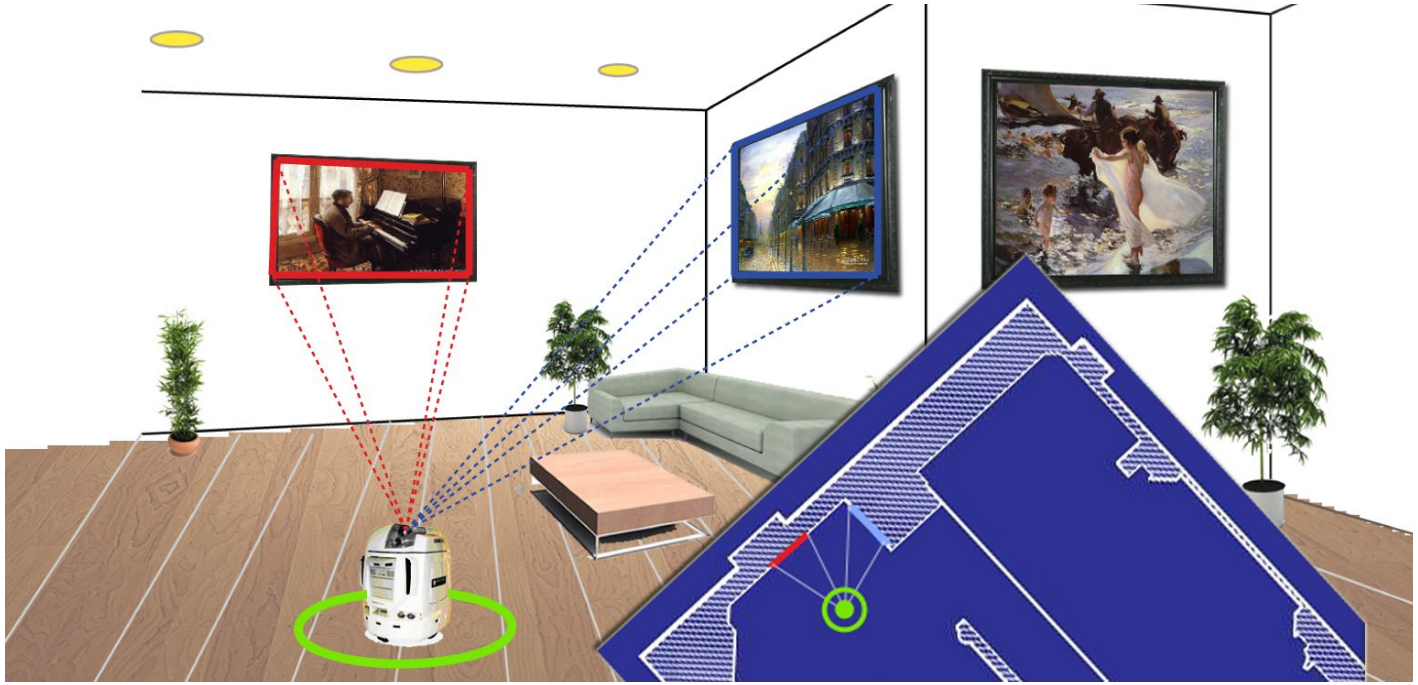
Dead-Reckoning(Motion)

- Keep track of initial position and the series of movements/actions that you made.
- Method: Take a “step”, compute new position.
- Also called odometry or path integration Example: **Inertial navigation systems** (INS)



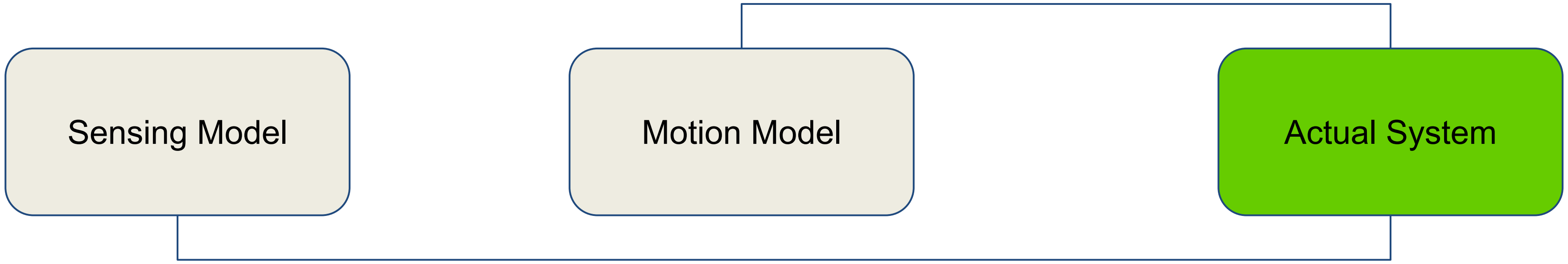
LandMark(Sensing) Based

- **How it works**
  - *Opposite of dead-reckoning!*
  - Use measurements to external landmarks of known position
  - Examples: visual landmarks, radio towers, GPS!



State Estimation (uncertainty in motion & sensing)

- **Key Idea: Combine Motion and Sensing**
  - **(Dead-reckoning + uncertainty)** + **(Landmarks + uncertainty)**
  - Each has error, but the error can be complementary
- **Kalman Filters**
- **Particle Filters (Monte Carlo Localization)**



Localization Techniques

- **Dead-reckoning (motion)**
  - Keep track of where you are without a map, by recording the series of actions that you made, using internal sensors. (also called Odometry, Path Integration)
- **Landmarks (sensing)**
  - Triangulate your position geometrically, by measuring distance to one or more known landmarks
    E.g. Visual beacons or features, Radio/Cell towers and signal strength, GPS!
- **State Estimation (uncertainty in motion & sensing)**
  - *Probabilistic Reasoning*
    - **Kalman Filters** (combine both motion and sensing)
    - Particle Filters (also known as Monte Carlo Localization)

Next Class

Robots Navigating

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

Thank You