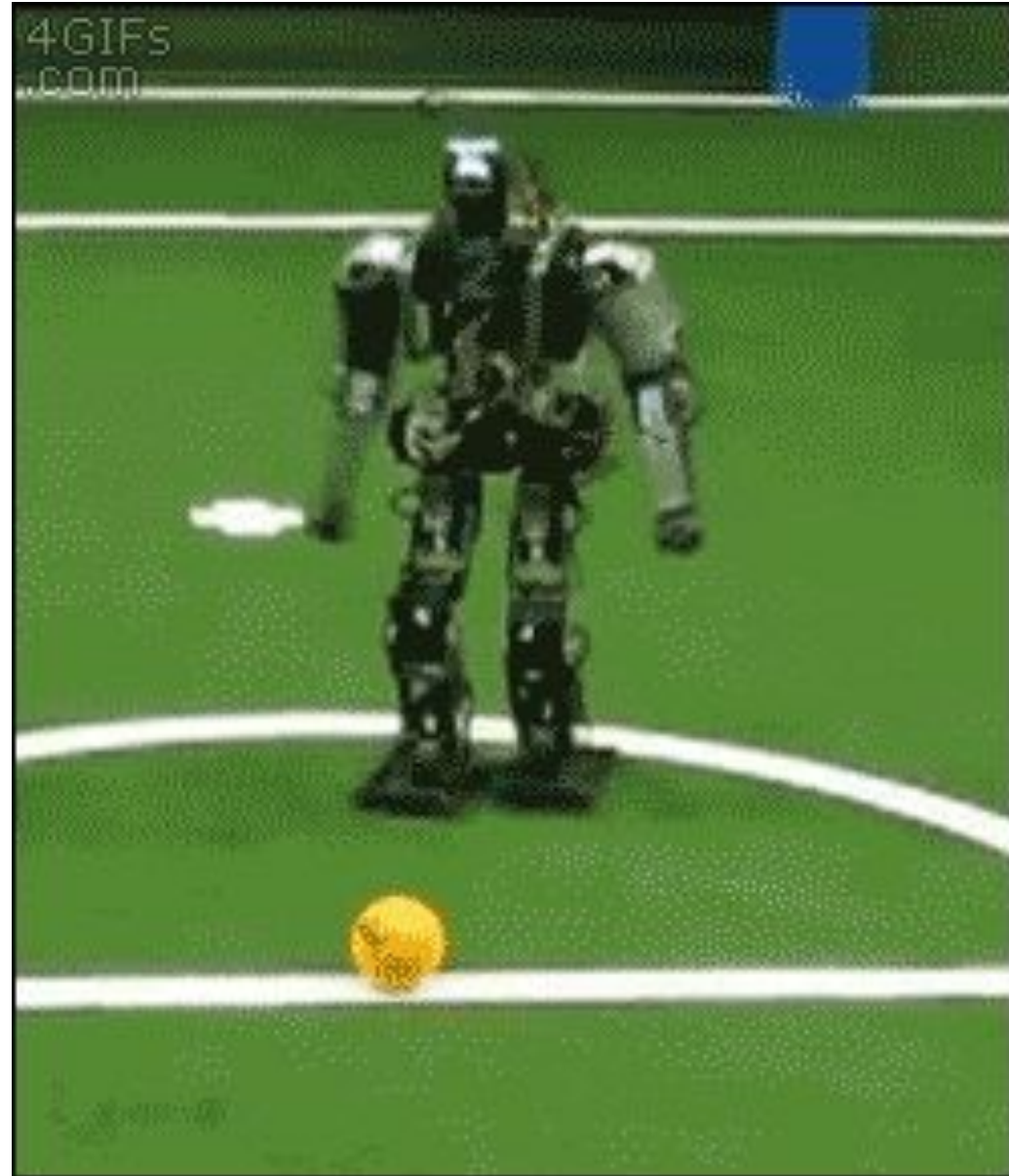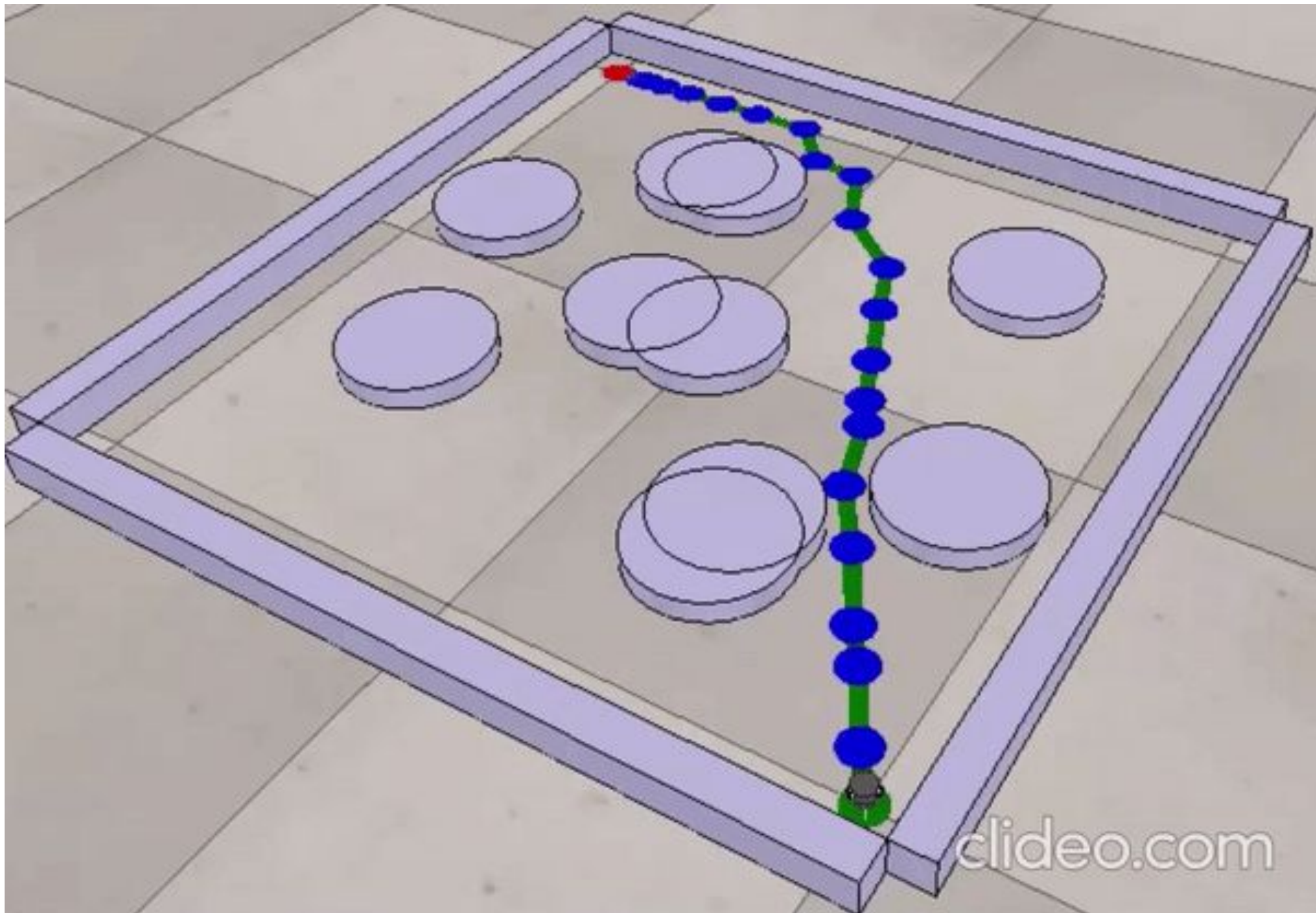# Introduction to Robotics
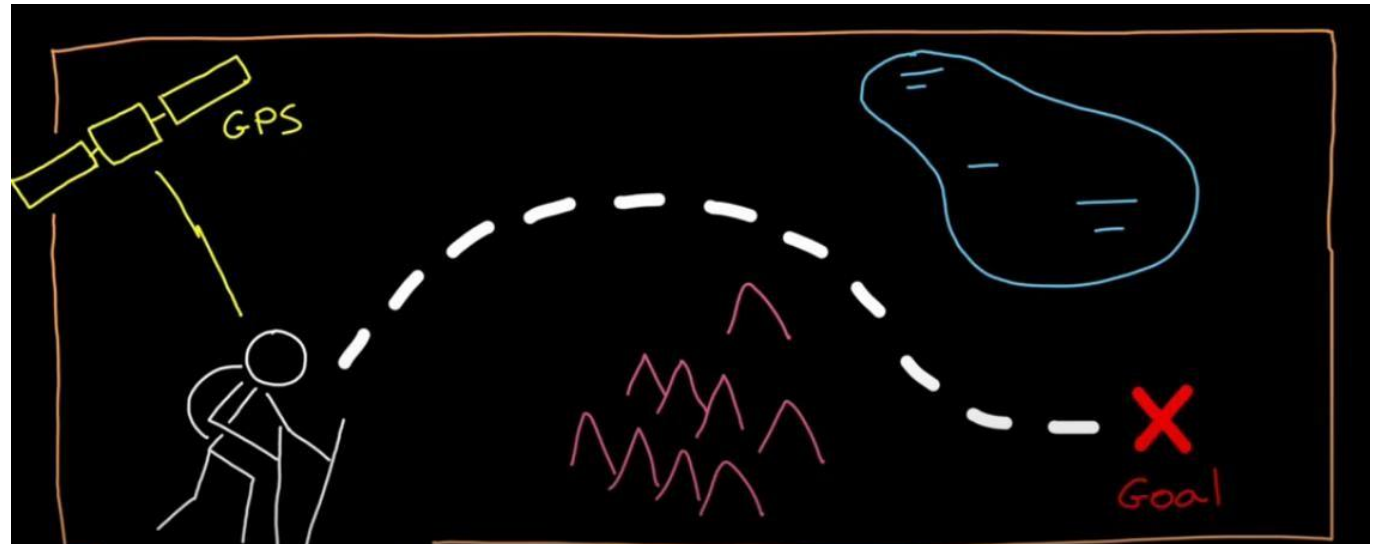# CSE 461

Lecture 8: Robot Navigation

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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

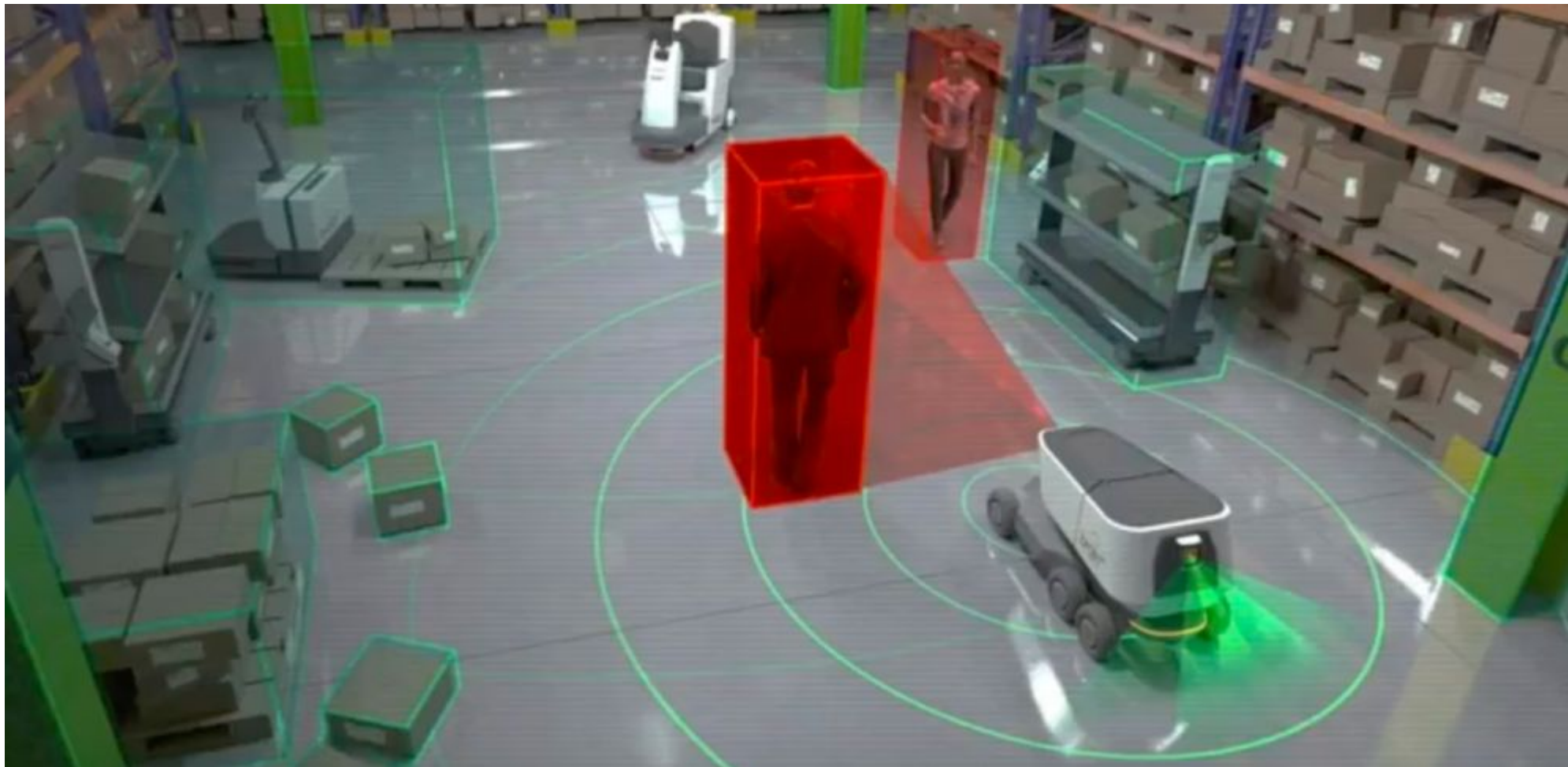
GOOGLE CAR

DILIGENT

COBALT(office)

SAVIOKE (hotels)

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?)

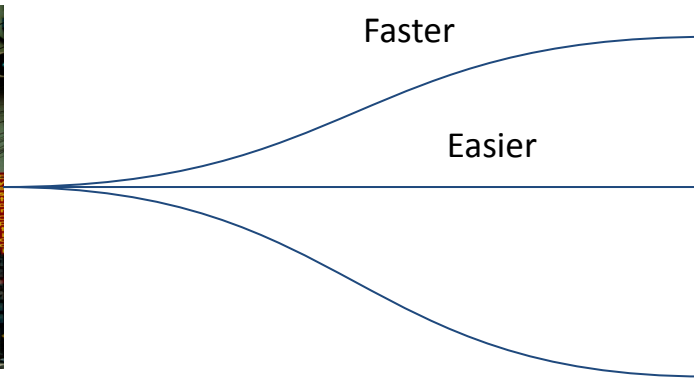We have to design the navigation system

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

Faster

Easier

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?

  - How precise is your motion control?

- Path Planning is best thought of as a Collection of Algorithms

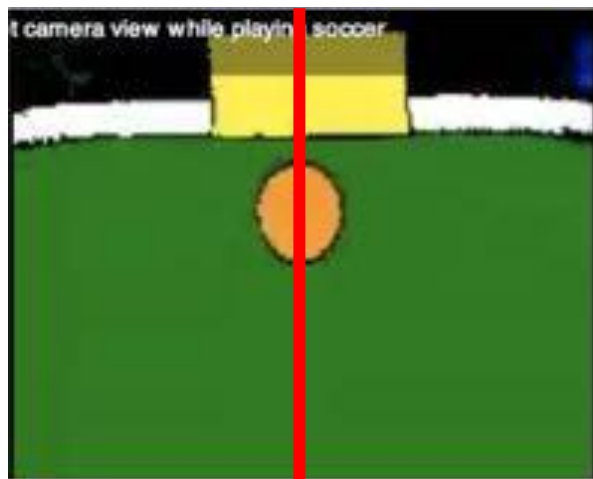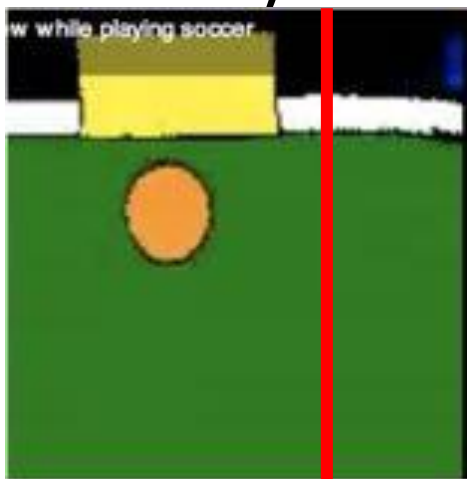- 3 Things need to consider: Environment, Success metrics, Robot capability.

We know our criteria 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

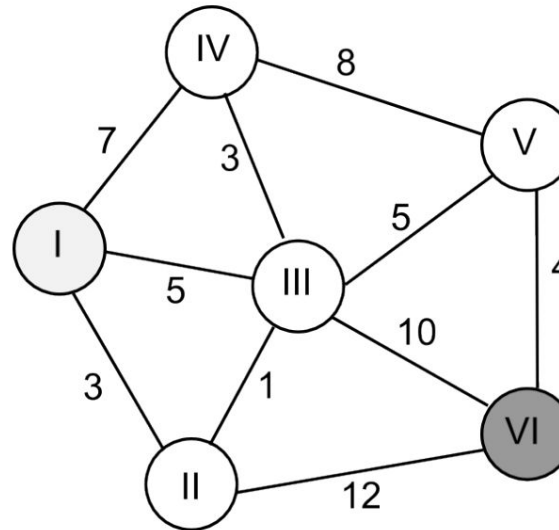# What if the map is given ?

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 do 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?

       Can you sense and record your own self-movement?

       Can you sense external things like landmarks?

       How certain are you about what you sense?

 Localization is a "collection of algorithms"
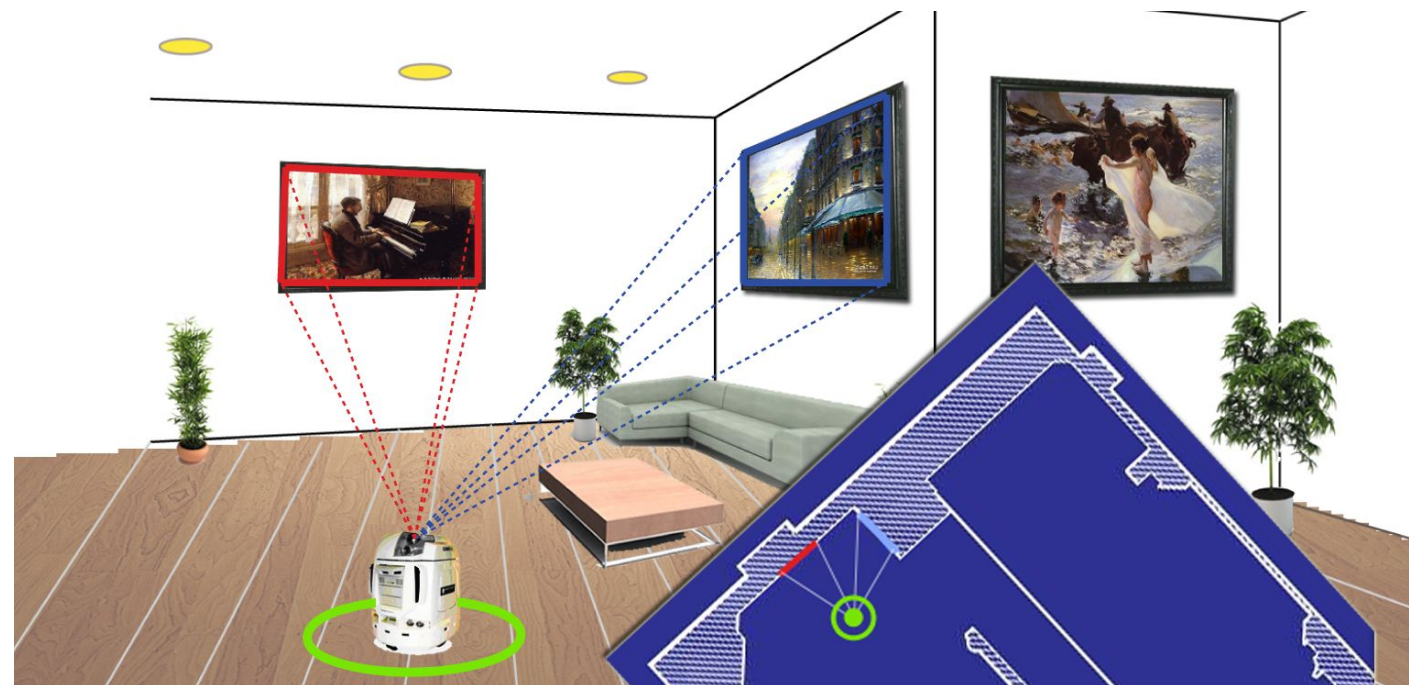
Dead-Reckoning(Motion)

- 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)
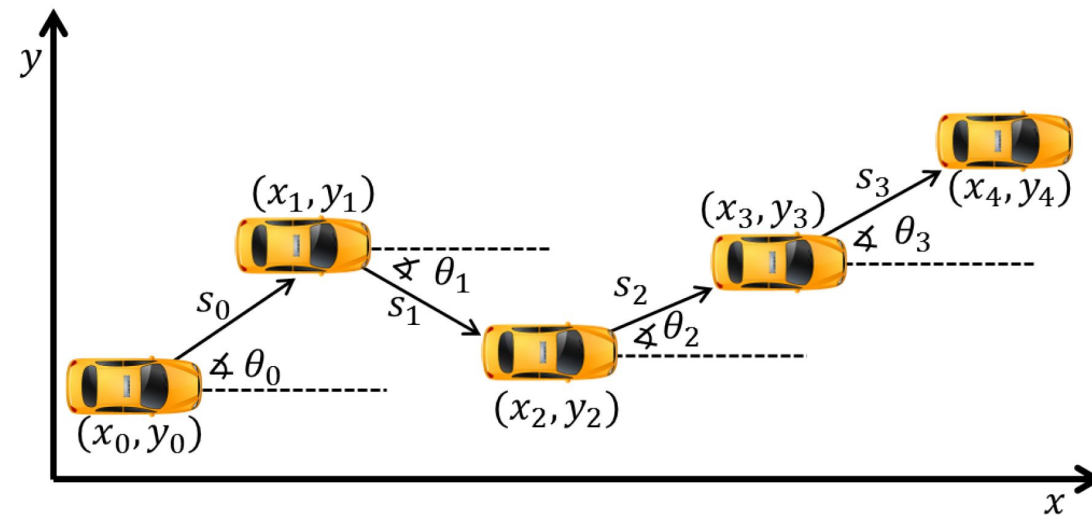
LandMark(Sensing) Based

- **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)**

Sensing Model	Motion Model	Actual System
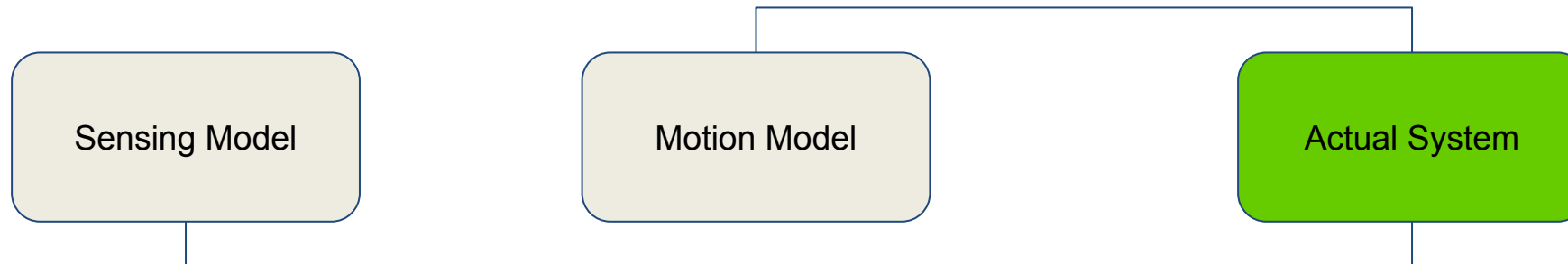
Localization Techniques

 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