Selected topics in Robotics

CS3243 Foundations of Artificial Intelligence

(Textbook section 25.1, 25.2, 25.3, 25.4, 25.6)
Slides due to Huang Weihua

Outline

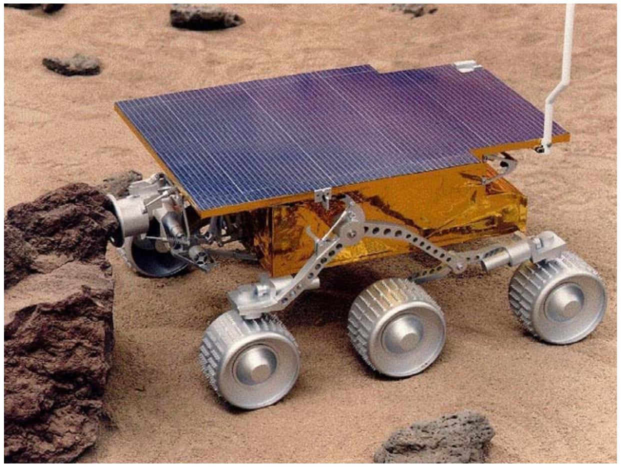
- Definition
- Hardware
  - Sensors
  - Effectors
  - Electric Motors
- Perception
  - Localization
- Motion Planning
- Move

Definition

- A robot is a physical agent equipped with sensors and effectors that can perform certain task in the physical world.
- Categories:
  - Manipulator: robot arms.
  - Mobile: environment navigation.
  - Hybrid: mobile + manipulator, e.g. humanoid robot.

Definition

- Example:



Hardware

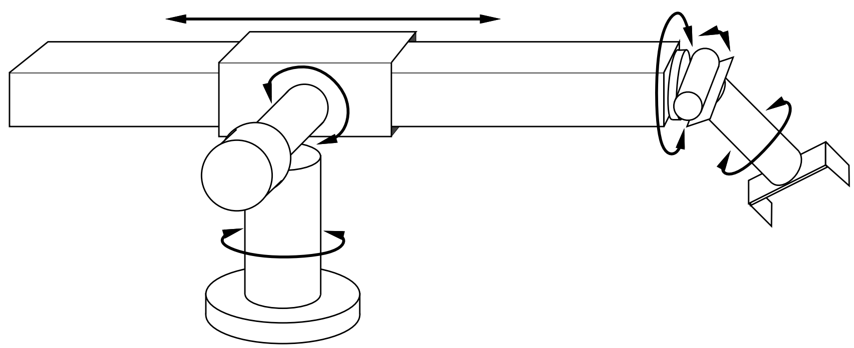
- Sensors: perceptual interface between the robot and the environment.
- Passive sensor: capture signals generated by other sources in the environment, e.g. a touch sensor.
- Active sensor: send energy into the environment and capture the reflected energy.

Hardware

- Sensor types
  - Range finder: measure distance to other objects in the environment, e. g. light sensor, sonar, GPS.
  - Imaging sensor: provides models and features in the environment, using computer vision techniques, e.g. camera.
  - Proprioceptive sensors: detects the state of the robot itself, e.g. rotational sensor.

Hardware

- Effectors: enables a robot to move and perform actions.
- Example:



Hardware

- Degree of freedom (DOF): independent direction in which one of the effectors can move.
- Example: an AUV has six degrees of freedom: (x, y, z) and three angular orientation.
- Kinematic state: set of all the degrees of freedom.

Hardware

- Effective DOF vs. Controllable DOF:
- A robot is nonholonomic if:

  # of effective DOF > # of controllable DOF

- A robot is holonomic if:

  # of effective DOF > controllable DOF.

Hardware

- Wheels vs. legs
  - Wheel-based designs are easier to implement (differential drive or synchro drive).
  - Legs can handle more rough terrain, but are mechanically difficult to build. (Dynamic stability and static stability)

Hardware

- Electric motor
  - Most popular mechanism to provides power to drive the effectors.
  - Actuation the manipulator and controls locomotion.

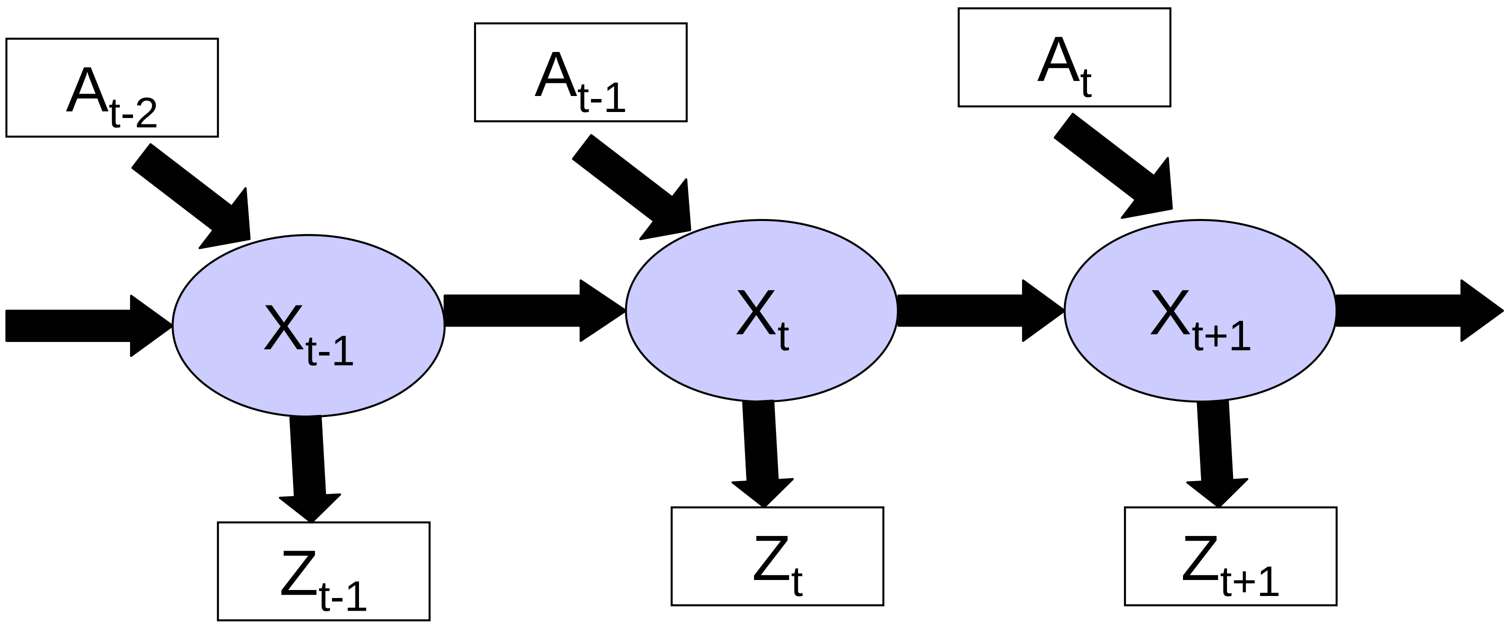
Robotic Perception

- Perception is the process of mapping sensor measurements into internal representations of the environment.

- Difficulties: environment is partially observable, unpredictable and dynamic.

Robotic Perception

- Bayes Network representation



Where A_i are the actions, X_i are the states and Z_i are the observations.

Robotic Perception

- Localization: determine the location of things in the environment.
  - Tracking: the initial location of an object is known.
  - Global localization: finding a target whose initial location is unknown.
  - Kidnapping problem: the target object is "kidnapped" to test the robustness of the robot.

Motion Planning

- Workspace: coordinates characterize the full state of the robot. (x, y, z, …)
- Configuration space: coordinates characterize the configuration of the robot's joints. (rotational angles etc.)
- Free space: all configurations that the robot is allowed to reach.

Motion Planning

- Cell-decomposition methods: divide the free space into a finite number of contiguous regions (cells).
  - Path planning => graph search.

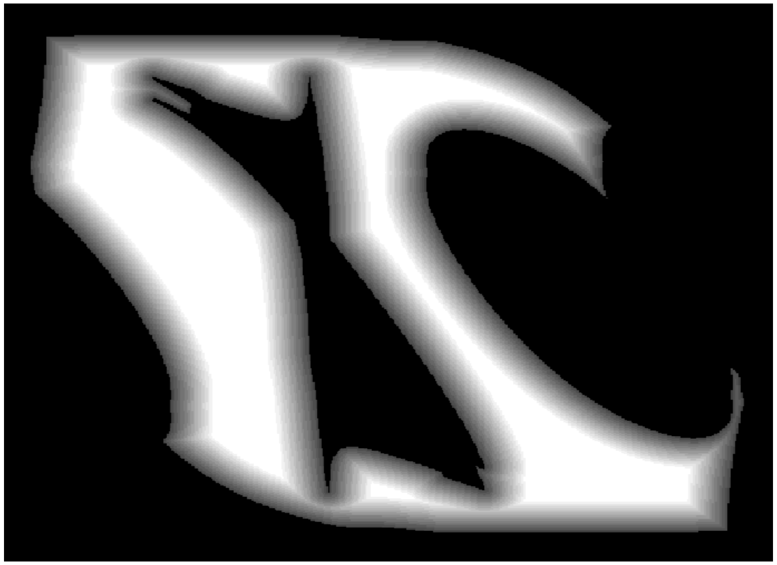
Motion Planning

- Simplest cell decomposition: cell = regular grid.
- Problem: too expensive for high-dimensional configuration space. Mixed cells make the method unsound and incomplete.
- Solution: subdivision and irregular cells.

Motion Planning

- Potential field: a function defined over the state space, whose value grows with the distance to the closest obstacle.
- Minimize the path lengths and stay away from the obstacles by following the smallest values.
- Problem: local minimum

Motion Planning

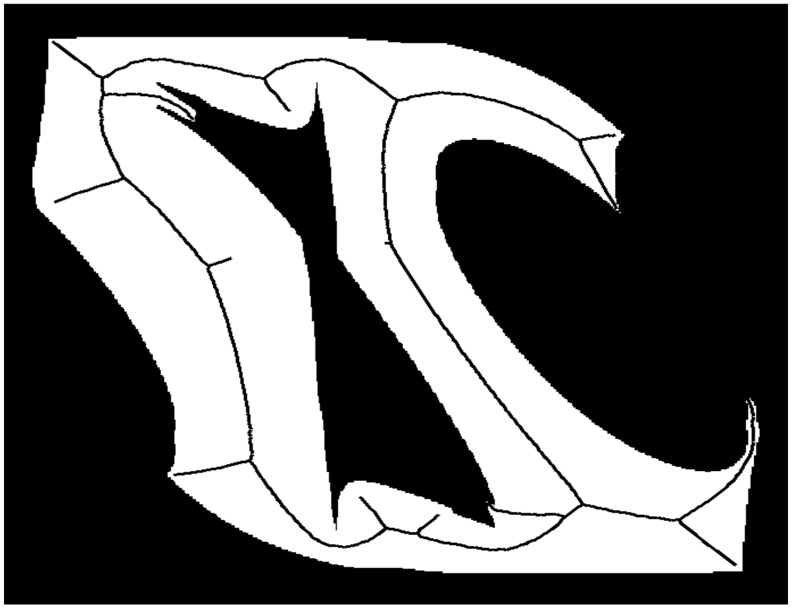


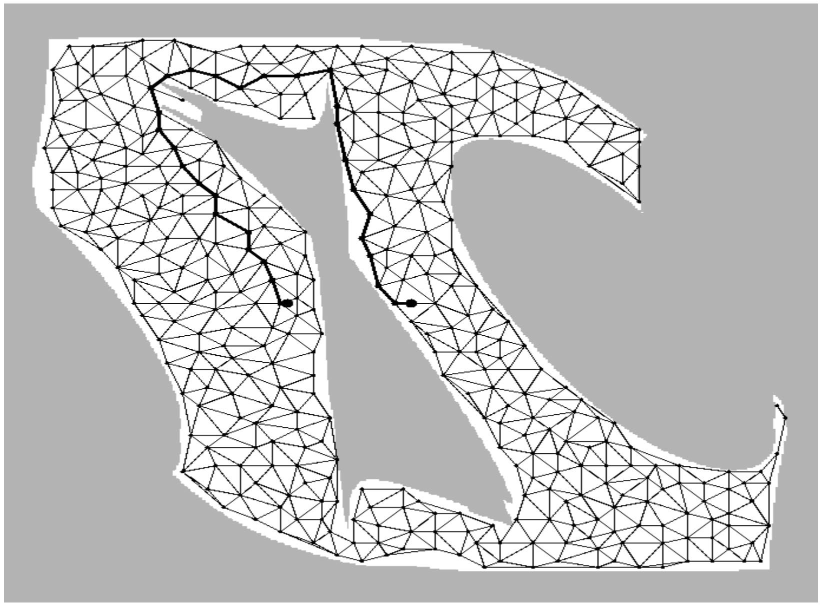
Motion Planning

- Skeletonization methods: reduce the free space to a one-dimensional representation.
- Voronoi graph: contains points that are equidistant to neighboring obstacles.
- Probabilistic roadmap: randomly generate candidates in the free space and link them.

Motion Planning

- Example:





Move

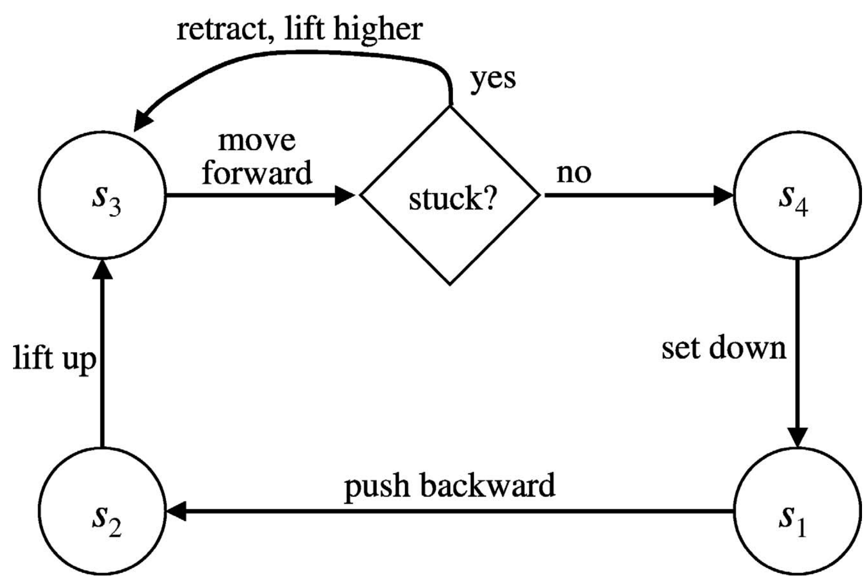
- Dynamic state: extends the kinematic state of a robot by modeling the velocities, which is more complex.

- In real-life, a simple kinematic path planner is used together with a controller to keep the robot on track.

Move

- Reference controller: keep the robot on a preplanned path.
- Optimal controller: optimize a global cost function, such as the potential field function.
- Reactive controller: reflex design that makes decision based on feedbacks.

Move



retract, lift higher
yes
move forward
stuck?
no
s_3
s_4
lift up
set down
push backward
s_2
s_1

(END)