Robots
Robotics as AI
Robotics

Shakey the Robot
1966 - 1972

First robot to combine reasoning and low-level action, an attempt at a truly integrated and complete AI system.
Robotics

High-level Reasoning

Discrete, abstract, symbolic.

PourTea:

Pre: HoldingKettle \land KettleFull

Effect: \neg KettleFull \land TeaPoured

Continuous, noisy, locally and partially observable, sensorimotor space.

Low-level Control
Robotics

Low-Level

Mid-Level

High-Level

High-level Reasoning

Low-level Control

(:action pick_up
 :parameters ()
 :precondition (and (symbol1) (symbol3)
 (symbol15) (symbol16) (symbol11))
 :effect (probabilistic
  0.0559 (and)
  0.9441 (and (symbol12) (not (symbol3)))
  (decrease (reward) 53.42))
 )
Kinematics

The first key question: where am I?

Relevant sensor: Encoders
Kinematics

Where’s my gripper?
Kinematics

Key idea: coordinate frame attached to rigid link.

Each link in the series has a transform matrix describing transform from link before it to its own coordinate frame.
Registering Sensor Data

Data given in the coordinate frame of the sensor.
Kinematics

Matrices linked together in a tree
Inverse Kinematics

The reverse question.

*Given a target pose in world-space, what joint values reach it?*
Motion Planning

start pose

goal
Control

Planning outputs a sequence of robot poses.

How to move directly to a pose from the current pose?
  • Must send force to motors.
  • How much?
  • When?
  • For how long?

**Control theory:**
  • How to apply torque to motors
  • Don’t overshoot
  • Don’t undershoot
  • Don’t destabilize the robot.
**Control**

**PID Control**

- Move towards goal point with speed proportional to:
  - Proportional to distance (reduce error)
  - Integral term (defeat residual error)
  - Differential term (to dampen)
Robots in Motion
Low-Level Perception

Lots of questions here.

*Simultaneous localization and mapping (SLAM)*

- Robots have limited perception.
- What does the building look like?
- Where is the robot in it?

(Freese et al.)
SLAM
1000 Kilometers Of Appearance-Only SLAM

FabMap 2.0
Robotics

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High-level Reasoning

Low-level Control

(:action pick_up2
 :parameters ()
 :precondition (and (symbol1) (symbol3))
 (symbol15) (symbol16) (symbol11))
 :effect (probabilistic
  0.0559 (and)
  0.9441 (and (symbol2) (not (symbol3)))
  (decrease (reward) 53.42))
 )
Mid-Level Goals

Given the ability to:

- Localize
- Navigate
- Motion plan
- Move to a given pose

… what next?

Object manipulation
Grasping

Where to grasp?

One approach:

- Generate large numbers of grasps (e.g., geometric)
- Train a grasp classifier to recognize good grasps

Grasping in Dense Clutter

Northeastern University
College of Computer and Information Science
Exploring Objects

How many degrees of freedom does an object have?
Exploring Objects
Learning Motor Skills

We’ve seen this in RL, but one more: **parameterized skills.**

General skills:
- Single skill to solve a *parametrized family* of problems.
- More flexible skills, avoids re-learning
Learning Motor Skills
Robotics

Low-Level

Mid-Level

High-Level

High-level Reasoning

Low-level Control

(:action pick_up2
 :parameters ()
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 (symbol15) (symbol16) (symbol11))
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  (decrease (reward) 53.42))
 )
Planning and Reasoning

Given:

- Localize
- Navigate
- Motion plan
- Move to a given pose
- Recognize objects
- Manipulate objects
- Learning skills

… what next?

Planning using these as a foundation.
Planning
Multi-Robot Planning

Decentralized, partially-observable MDPs

Objective: Push the boxes (big and small) from D1 and D2 to the goal as quickly as possible.
Robocup
Cobots

1,000 km of autonomous operation
Robotics