Working with a Real Robot (Lecture 3)

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Conflict of Interest Statement

I own equity in and work for Hello Robot Inc., a company commercializing robotic assistance technologies.

Working with a Real Robot (Lecture 3)

- Modeling wisdom
- Real robot
  - ROS
  - Kinematic modeling
  - Visual servoing

Modeling Wisdom

"All models are wrong, but some are useful." - George Box

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There is no true substitute for the world. It is unique with incredible richness and complexity, much of which is unobservable. We can only model specific facets of the world at any given time.

A dangerous fallacy is to confuse the world and models of the world. This has been a remarkably common issue in robotics.

Fortunately, simple models can be powerful. A simple system can result in robust behavior in the real world.

Engineering Approach

Create a real-world system and a model of the system that match each other well.

Digital systems

Mechanical systems

Electrical systems

Synthetic biology

Building Blocks for Engineered Systems

Evolved together with modeling tools

Repeatable

Predictable

Manufacturable

A very small subset of real-world phenomena

A closed world

Not optimal out of the space of real-world systems (bigger, heavier, higher energy, …)

Example from Programming

https://wiki.c2.com/?PrimitivesAndMeansOfComposition

https://en.wikipedia.org/wiki/Structure_and_Interpretation_of_Computer_Programs

https://sarabander.github.io/sicp/html/1_002e1.xhtml

- **primitive expressions**, which represent the simplest entities the language is concerned with,
- **means of combination**, by which compound elements are built from simpler ones, and
- **means of abstraction**, by which compound elements can be named and manipulated as units.

The Engineering Approach Breaks Down

Robots that go outside of closed, engineered worlds interact with systems that are unmodeled, poorly modeled, or partially modeled. This has significant implications.

Humans, which have the ultimate importance for caregiving robots, are one of the greatest sources of complexity for a robot.

Empiricism Becomes Important

Scientific approaches become more important

Corner cases can kill

Generalization to new circumstances

Multiple models that operate over limited regimes

Handling variation

Machine learning

Deep learning

How should robots handle people?

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As much as possible, give people control over the robot.

What models work well in robotics?

Kinematic

Dynamic

Kinematics

- http://en.wikipedia.org/wiki/Kinematics
    - *"Kinematics is the branch of classical mechanics which describes the motion of points, bodies (objects) and systems of bodies (groups of objects) without consideration of the causes of motion."*
- Describes the geometric configuration of the world over time.

Dynamics (Kinetics)

- http://en.wikipedia.org/wiki/Dynamics_(mechanics)
  - *“Dynamics is a branch of physics (specifically classical mechanics) concerned with the study of forces and torques and their effect on motion…”*
- Goes beyond kinematics to consider the forces and torques that cause changes to the geometric configuration of the world over time.

Move to the Whiteboard

- Forward kinematics: ee_xyz = F(theta)
- Inverse kinematics: theta = F^-1(ee_xyz)
- Real robot
    - RViz URDF visualization
    - How good is the robot’s model of itself?
        - Qualitative visualization using point clouds
        - Quantitative characterization of fit using fiducials
    - Approaches to dealing with model error
        - Calibration (reduce model error)
        - Feedback control
            - Visual servoing
                - Can be remarkably robust
                - Just need to reduce the error at each step (don’t need exact gradient)
                - Relates to iterative optimization, gradient descent, replanning, model predictive control (MPC), and more
            - Robot demo and interactive Jupyter notebook https://github.com/prof-charlie-kemp/robotic-caregivers-2020

Jupyter Notebook with Simple Visual Servoing Model

- Use binder to run the Jupyter notebook
  - Go to the root directory with the following link
    - https://mybinder.org/v2/gh/prof-charlie-kemp/robotic-caregivers-2020/master
  - Go to ./jupyter_20200412/visual_servo.ipynb
- Use the notebook
  - See image to left
  - Press the run button for each code block
  - Move the sliders