

# Lecture 1. Introduction

Matthew T. Mason

Mechanics of Manipulation  
Spring 2012

Syllabus

Motivation

Course  
organization

What is  
manipulation?

Robotic manipulation

Structure and uncertainty

Animal manipulation

Human manipulation

Discussion

# Today's outline

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What is manipulation?

- Robotic manipulation

- Structure and uncertainty

- Animal manipulation

- Human manipulation

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- ▶ Kinematics.
- ▶ Kinematic manipulation – when forces can be neglected.
- ▶ Statics.
- ▶ Static manipulation – immobilizing stuff.
- ▶ Quasistatic manipulation – moving stuff slowly.
- ▶ Dynamics.
- ▶ Dynamic manipulation – moving stuff quickly.

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# Why study the mechanics of manipulation?

## Science

To satisfy our curiosity, we want to understand manipulation.

## Science serves Engineering

To build robots, we need to understand manipulation.

## ... and Meta-engineering

For a robot to autonomously solve novel tasks, the robot itself needs to understand manipulation.

## Engineering serves Science

To test a theory of manipulation, build a robot embodying that theory.

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## Science

To test a theory of manipulation, build a robot embodying that theory.

- ▶ Judging from the videos, *every* theory of manipulation works!
- ▶ When watching a robot video, think like the mathematician in the Scottish sheep joke (see next slide).
- ▶ When testing a bot, define a task domain, sample it well, publish the failures as well as the successes.
- ▶ Use standard data sets when available.
- ▶ Publish the code when possible.

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# The Scottish sheep joke

An astronomer, a physicist and a mathematician were holidaying in Scotland. Glancing from a train window, they observed a black sheep in the middle of a field.

"How interesting," observed the astronomer, "all Scottish sheep are black!"

To which the physicist responded, "No, no! *Some* Scottish sheep are black!"

The mathematician gazed heavenward in supplication, and then intoned, "In Scotland there exists at least one sheep, at least one side of which is black."

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- ▶ Lectures MW 1:30-2:50. 5 minute break.  
(Use fridays for more flexible scheduling?)
- ▶ Textbook: *Mechanics of Robotic Manipulation*, by Matthew T. Mason. MIT Press: Cambridge, MA. 2001.
  - ▶ There is an online copy available free to subscribers. CMU is a subscriber. Available at:  
<http://cognet.mit.edu/library/books/view?isbn=0262133962>
- ▶ Grading. Assignments 60 percent, term project 40 percent.

# What is manipulation?

## Robot in kitchen



Intel Research Pittsburgh. Open House. 2008. (Siddhartha Srinivasa)

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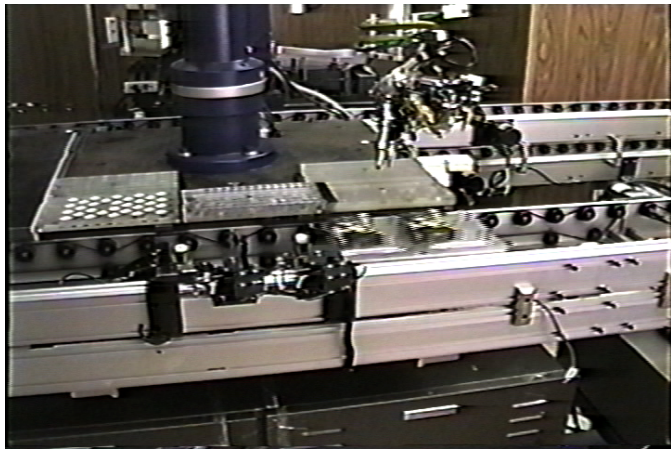
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# What is manipulation?

Robot in factory



Sony Smart Cell. Manipulation Lab, CMU RI.

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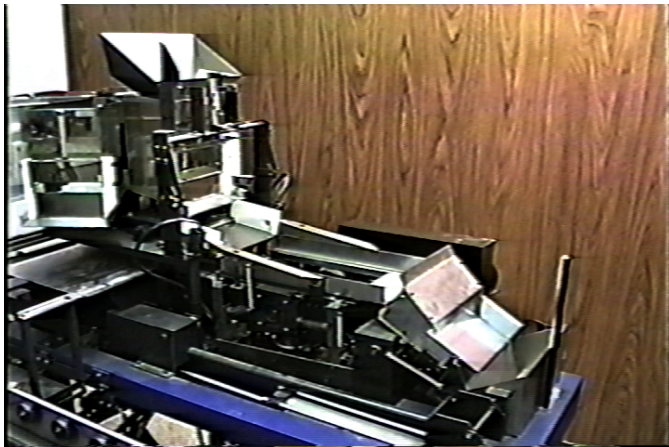
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Robot in factory



Sony APOS. Manipulation Lab, CMU RI.

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# What is an unstructured environment?

Structure definition one.

- ▶ Some say the factory is a structured environment; the kitchen is an unstructured environment.

## Definition (co-engineering)

A **structured environment** is a task environment that was co-engineered, with the robot, to solve the task.

## Example

Placing navigation beacons to simplify mobile robot navigation.

## Example

Deploying equipment to present parts at precise locations to simplify automated assembly.

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# What is an unstructured environment?

Structure definition 2.

## Definition (engineering)

A **structured environment** is a task environment that was engineered for the solution of the task.

## Example

Countertops in kitchens, which simplify meal preparation.

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# What is an unstructured environment?

Structure definition 3.

## Definition (regularities)

A **structured environment** is a task environment with regularities that simplify a task.

## Example

The numerous vertical edges in urban environments, which simplifies vision.

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# What is manipulation?

## What is structure?

- ▶ Structure 1 (co-engineering)  $\subset$  Structure 2 (engineering)  $\subset$  Structure 3 (regularities)
- ▶ The kitchen was engineered to simplify food preparation. But it was not co-engineered with humans. (Or . . . perhaps we have co-evolved with our tools.)
- ▶ A robot may be designed to take advantage of the kitchen's engineering. The more similar to a human, the closer it gets to the appearance of co-engineering. But to the robot engineer, the difference is enormous.
- ▶ What about modifications to the environment by the robot itself? Ants leaving tracks.

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# What is manipulation?

## Structure and uncertainty

- ▶ Uncertainty is a big problem.
- ▶ Structured environments present opportunity to reduce uncertainty.
- ▶ Kitchens are structured primarily for people.
- ▶ Automated factories are structured primarily for robots.
  - ▶ Uncertainty is often reduced, but not eliminated. Reducing uncertainty costs money. Imagine the cost of a dishwasher manufactured with sub-micron tolerances.
  - ▶ The principles of eliminating uncertainty, or tolerating it, apply in both types of environments.
  - ▶ Consequently, the factory is good subject for study, as well for application of robotic technology.

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# What is manipulation?

Viki the chimp



Hayes and Hayes, 1952.

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Hayes and Hayes, 1952.

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# What is manipulation?

Chimp termiting

**ARKive**  
IMAGES OF LIFE ON EARTH

For thousands of videos, images and fact-files illustrating the world's species visit [www.arkive.org](http://www.arkive.org)



**ARKive**

[www.arkive.org](http://www.arkive.org)

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BBC and Granada Wild. [www.arkive.org](http://www.arkive.org).

# Chimps v humans

"It is a little daunting to discover—on the very technological grounds on which human superiority is often claimed—that after months of apprenticeship, human scientists cannot do as well as preadolescent chimps. Teleki remained generous and good—natured about his failure. In the acknowledgments at the end of the paper, among thanks to various organizations for financial and logistical support, there appears this sentence: "I am, in addition, more than grateful to the patient and tolerant Leakey, whose termite-collecting skills so out-stripped mine."

<http://www.mc.maricopa.edu/dept/d10/asb/primates/termiting.html>

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# What is manipulation?

Human



The French Chef. WGBH Boston.

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Human



da Vinci Surgical System. Kanazawa University.

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Credits?

# What is manipulation?



Michael Moschen in Motion. National Geographic.

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# What is manipulation?

Further reading.

There is some additional material posted on the course web page.

- ▶ The role of the hand in human evolution.
- ▶ Comparisons of humans and animals, specifically a rock fight between humans and baboons.
- ▶ More information on termite fishing.

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# Discussion?

Unresolved questions.

- ▶ What is manipulation?
  - ▶ Can we write a precise definition?
  - ▶ Can we produce a taxonomy?
  - ▶ How do we measure progress?
- ▶ How far have we come? How far can we go? How long will it take?
- ▶ What is generality?
- ▶ How do we compare different manipulation tasks, different manipulation systems?

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