CSCI–4964/6963 Advanced Robotics
Spring 1999

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office:	Amos Eaton 111, x8189
office hours:	Mondays 1–2pm or by appointment
classroom:	Carnegie 113
times:	MWF 10–11am*
text:	none (readings to be distributed in class)

1 Course description

This course will cover topics in robotic manipulation and mobile robotics. It is intended to give the student a broad background in these areas, familiarity with the state of the art, and an understanding of current research areas. The first third of this course will cover manipulation; the last two thirds, mobile robotics.

Robotic manipulation is concerned with how to manipulate objects (to accomplish some task) rather than on how to control a robotic arm. In fact, many applications of robotic manipulation (or the "mechanics of manipulation") are in systems that do not have a robotic arm per se. Robotic manipulation, then, is concerned with:

- phenomena governing object motion — kinematics, dynamics, contact, friction, and impact;
- different modes and strategies for manipulation; and
- creating plans — sequences of actions on a system that accomplish some goal.

Robotic manipulation can be applied to parts feeding systems for assembly lines or to dynamic manipulation tasks such as juggling.

Mobile robotics is the study of robots that move around in the world; consequently, the problems of mobile robotics are quite different than those of manipulation. Our study of mobile robotics will center on:

- understanding the components and design of mobile robots;
- localization and planning — how a robot knows its location and determines how to move to a goal location; and
- robot architecture — the internal (software) structure of robots to support high level goals.

We will be reading papers from the literature throughout the term. A final project is also an important part of this course.

Prerequisites

There are no formal prerequisites, however I will depend on some technical background in a number of areas, particularly math (calculus, linear algebra, and differential equations) and computer science (algorithms and programming). Some homework assignments will have a programming component.

2 Course activities and grading

There will be a variety of activities in this class:

- *Assignments* — there will be 4 or 5 assignments throughout the semester which will be designed to reinforce or complement topics covered in class. Assignments are due at the beginning of class.
- *Reading reports* — a 0.5–1 page summary/critique of the papers to be discussed. These are due on the classday before the paper discussion. Their purpose is to make you read carefully and to think critically about what you are reading.
- *Paper presentation* — for each paper to be discussed, a pair (?) of students will be assigned to present the paper at the beginning of the class and lead discussion that day. Each student is only expected to do this once during the semester.
- *Final project* — students will work in teams of 2–4 students on a project related to the topics covered in this class. Experimental projects are particularly encouraged; other options include software/simulation projects or an in-depth study of a topic through several journal and/or conference papers. An in-class presentation and a written report will be required. More information on the final project will be given later in the semester.

Your grade will be determined as follows:

30%	Assignments (weighted appropriately)
30%	Reading reports, paper presentation, and class participation
40%	Final project

Academic honesty

I expect anything you turn in with your name on it to be your own work (or your team's work on the final project report).

I encourage you to discuss readings and assignments with classmates or others. However, these discussions should focus on ideas and clarifications rather than on the details of the work to be turned in.

Examples of appropriate discussion: "Do you think deliberative architectures have inherent limits?" "Can you show me where Equation 7 comes from in this paper?" "Let's talk about the merits of the different approaches to this assignment."

Examples of inappropriate discussion: "What did you get for problem 2?" "Can I take a look at your solution?" "Let's sit down and write out this answer together."

3 Tentative schedule

Mon. Jan 11 Introduction & overview; What is a robot?

Read for Wed: Mason, "Preface," *Mechanics of Robotic Manipulation*.

Assignment 1 out, due Fri. Jan. 15.

3.1 Manipulation

Wed. Jan. 13 Introduction to Manipulation; Basics: kinematics and COR

Fri. Jan. 15 Basics: physics, friction, impact

Assignment 1 due.

Mon. Jan. 18 MLK holiday.

Wed. Jan. 20 Basics: classical planning (search, backchaining)

Fri. Jan. 22 Paper discussion: Böhringer, Bhatt, and Goldberg, "Sensorless Manipulation Using Transverse Vibrations of a Plate," ICRA 95.

Mon. Jan. 25 Grasping — force and form closure, grasp planning

Assignment 2 out, due Mon. Feb. 8.

Wed. Jan. 27 Pushing

Fri. Jan. 29 Paper discussion: Sakaguchi, Masutani, and Miyazaki, "A study on juggling task," IROS 91; and Bühler and Koditschek, "From stable to chaotic juggling: theory, simulation, and experiments," ICRA 90.

Mon. Feb. 1 Introduction to nonholonomic motion planning

Wed. Feb. 3 Tapping

Fri. Feb. 5 Paper discussion: Lynch and Mason, "Stable Pushing: Mechanics, Controllability, and Planning," IJRR?

Mon. Feb. 8 Planners in control loops?

Assignment 2 due.

Wed. Feb. 10 State estimation?

Fri. Feb. 12 Paper discussion: TBA.

Mon. Feb. 15 Mid-semester break.

3.2 Mobile robotics

Wed. Feb. 17 Introduction to Mobile robotics; Overview and design of mobile robots

Assignment 3 out, due Mon. Feb. 22?

Fri. Feb. 19 Locomotion and configuration

Mon. Feb. 22 Power systems

Assignment 3 due?

Wed. Feb. 24 Sensing: Sonars, cameras, etc.

Fri. Feb. 26 Localization

Mon. Mar. 1	Environment representation (Maps)
	Assignment 4 out, due Mon. Mar. 22.
Wed. Mar. 3	Introduction to path planning: basics, cellular approaches
Fri. Mar. 5	Paper discussion: TBA (dead reckoning)
	Tentative project proposals due.
Mar. 8–12	Spring break
Mon. Mar. 15	Path planning — configuration space
Wed. Mar. 17	Path planning — nonholonomic
Fri. Mar. 19	Paper discussion: TBA (path planning).
	Project proposals due.
Mon. Mar. 22	Control of mobile robots
	Assignment 4 due.
Wed. Mar. 24	Control of mobile robots
Fri. Mar. 26	Paper discussion: TBA (path planning)
Mon. Mar. 29	Project updates.
Wed. Mar. 31	Introduction to mobile robot architectures
Fri. Apr. 2	Paper discussion: Brooks, Subsumption architecture.
	Assignment 5 out, due Mon. Apr. 12?
Mon. Apr. 5	Project updates.
Wed. Apr. 7	Mobile robot architectures.
Fri. Apr. 9	Paper discussion: TBA (architectures)
Mon. Apr. 12	Project updates.
	Assignment 5 due?
Wed. Apr. 14	Mobile robot architectures.
Fri. Apr. 16	Paper discussion: TBA (architectures)
Mon. Apr. 19	Collaborative mobile robotics.
Wed. Apr. 21	Collaborative mobile robotics.
Fri. Apr. 23	Project presentations.
Mon. Apr. 26	Project presentations.
Wed. Apr. 28	Project presentations.

Key to source abbreviations:

ICRA	IEEE International Conference on Robotics and Automation
IROS	IEEE/RSJ International Conference on Robots and Systems
IJRR	International Journal of Robotics Research
TRA	IEEE Transactions on Robotics and Automation