CDS 270
Mechanics and Control of Multi-Fingered Robotic Grasping
(Spring 2011)

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Class Meeting Time: we will try to find a meeting time that accomodates as many students as possible.

Scope and format of CDS 270

This course will focus on *multi-fingered robotic grasping*. The first portion of the course will focus on the basic mechanics of multi-fingered grasping, while the latter portion of the course will focus on issues of multi-fingered grasp planning and hand control. Because there is a reasonably well developed academic theory of grasp mechanics, the first portion of the course will rely upon textbooks, while the latter portion will consist more of a survey of the recent research literature on grasp planning and control. The goal of this course is to give students a grounding in robotic grasp mechanics, and an appreciation of the current research issues in grasp planning and control.

Topics to be Covered:

Part I:

- Basic Review of Rigid Body Kinematics
- The configuration space (c-space) representation of an object
- Wrenches and velocities
- Non-smooth calculus
- 1^{st}-order Force Closure (wrench resistant) grasps
- Force Closure via Linear Matrix Inequalities (LMIs)
- 1^{st}-order Form Closure (immobilizing) grasps
- Differential Geometry of curves and surfaces
- 2^{nd}-order immobilizing grasps

Part II:

- Algorithms for computing force closure (wrench resistant) Grasps
- Algorithms for computing form closure (immobilizing) Grasps
- Caging grasps
- Controllability and force closure
- Grasp metrics and grasp optimization
- Grasp execution and monitoring
- Regrasping.

Because of time constraints, the related and interesting problems of sensing for manipulation will not be covered.

Course References

There will be two main texts for this course

1. R. Murray, Z. Li, and S. Sastry, A Mathematical Introduction to Robotics, CRC Press. (the acronym "MLS," based on the authors' last names, will be used to refer to the this text). The 1^{st} edition of this book is now freely available on-line. There is a link to the on-line text on the course website. Some of you may wish to buy the book (e.g. it's available from Amazon). If you wish to buy a used version of the text, note that there is a second edition with some of the errata from the first edition corrected. Either edition is fine for the course. We will use only portions of chapters 2, 3 and 5.
2. J.W. Burdick and E. Rimon, A Geometric Introduction to the Mechanics of Bodies in Contact, with Applications to Grasping, Fixturing, and Quasistatic Locomotion. This manuscript is currently in preparation. Relevant chapters will be distributed freely as needed.

For the second portion of the course, relevant research papers will be distributed in class and posted on the class web site.

Course Prerequisites

The course assumes some basic knowledge in linear algebra (such as eigenvalues and eigenvectors). Most other mathematical concepts will be reviewed or introduced as needed. Students who have completed Math 2 or the equivalent should have adequate preparation. Some prorgramming experience will be required. Most homework problems or projects requiring computation can be accomplished in MATLAB or Mathematica.

Course Mechanics and Grading

The course-work will consist entirely of homework and a take-home final exam. A final project, whose content is approved by the course instructor, can be substituted for the final exam. The final project may consist of an analysis, simulation, or experimental project related to the course topics.

The course grade will be computed as follows:

Homework (approximately 6 sets)	70%
Final Exam (or project)	30%

The homework is not intended to be difficult, but rather to reinforce the topics presented in the lectures and the books/papers.

Course Web Site and Course Materials: The web site for this course can be found at:

http://robotics.caltech.edu/∼jwb/courses/CDS270.html

This site will contain copies of homework assignments, homework solutions, and most class handouts. Important information about the class, such as changes in due dates, homework errata, etc. can be found in the "Bulletins" section. You should visit this site if you miss class, as there will be no excuses for being uninformed. Most of the course reading material will be distributed in class, and copies posted on the course website. A very few handouts will not be available electronically–copies will be kept in the office of Mrs. Maria Koeper (Room 321 Thomas).