MAE 413/513: Robotic Mobility and Manipulation

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Course Description

This course develops various modeling, analysis, control and optimization techniques in the context of harnessing the mobility and manipulation capabilities using articulated multi-body mechanical systems (such as robot manipulators, ground and aerospace vehicles). Towards this end, the course merges and applies mathematical tools from kinematics, dynamics, nonlinear systems theory, motion planning, and optimization to examine and enhance performance of such robotic mechanical systems for various real-life applications.

Topics

1 **Introduction**
- Current state-of-the-art in mobility and manipulation.
- Challenges and research directions

2 **Motivating Case Studies**
- Serial Chain Robots (brief review)
- Parallel manipulators (kinematics, dynamics and design and calibration)
- Wheeled Mobile Robots (nonholonomic constraints, modeling, analysis and control)
- Mobile Manipulators (serial/parallel/mobile combinations of above)

3 **Formulation of Kinematics/Dynamics (Modeling)**
- Development of equations of motion of various series/parallel and hybrid mechanical systems can pose considerable challenges.
- What are the various options to systematically develop the governing equations of motion?
- Constrained motions and forces are inevitable in any robotic system that interacts with a dynamic environment OR with other robotic systems. e.g. grasping/contact

4 **Motion Generation (Analysis)**
- Motion planning in high-dimensional configuration spaces is computationally very expensive.
- What are suitable approaches to generate motion for mobile manipulators operating in dynamic environments?

5 **Efficient Dynamic Simulation (Analysis)**
- Since mobile manipulation platforms systems are very complex, expensive, and potentially fragile machines, simulation becomes an increasingly important means of performing experimental validation for research.

6 **Coordination of Mobility and Manipulation (Analysis)**
- The combination of mobility and manipulation capabilities usually results in redundant systems.
- The redundancy can be exploited to coordinate mobility and manipulation intelligently.

7 **Operational Space Control / Control (Analysis)**
- Operational space control aims to specify and control motion at the end-effector, rather than in terms of joint motion.

Prerequisites

- This course is open to all mechanical engineering graduate students (having taken MAE 493/593 Math Methods in Robotics would be useful but not necessary). If you are not a graduate student in mechanical engineering or if you are an undergraduate student, you must talk to me before registering for the course.
- Students are expected to have studied kinematics and kinetics in a sophomore level course and must be familiar with Newton's laws and their application to particles in two and three dimensions.
- We will assume that everybody is familiar with vector analysis (vectors & matrix manipulation) and linear algebra (matrix solution of linear systems), and has had a basic course in ordinary differential equations and their computational solution.
- Finally, we will make considerable use of MATLAB and MAPLE (or Mathematica) to solve examples.

Texts

Reading assignments will be based on papers/handouts but frequent reference will be made to:

- Tsai, L.W., Robot Analysis, The Mechanics of Serial and Parallel Manipulators, John Wiley & Sons, Inc., 1999.
- J. Angeles, Fundamental of Robotic Mechanical Systems, Springer, 1997.
- Spong, M.W. and Vidyasagar, M.M., Robot Dynamics and control, John Wiley & Sons, Inc., 1989.

Evaluation

- Reading assignments, problem sets, and projects will be announced in class or via e-mail, and be available through the UBLearns (see Course Documents and Assignments).
- All assignments and projects will be done by students in groups of two.
- There will be approximately one homework assignment every 1-2 weeks. Problem sets will be due one week after they are assigned.
- Only selected problems from each set will be graded.
- No credit will be given for late assignments (demonstrations or reports). Under special circumstances, exceptions may be made, but only if prior arrangements are made with me at least 3 days in advance of the due date.
- At the current time, two mid-term exams and a final project is also planned. However I reserve the right to merge the final project with the second midterm based on the progress during the semester.
- The preliminary grading scheme breakdown is as follows:

Homework Assignments	25%
Midterm Examinations (1-2)	25%
Final Project	25%
Final Examination	25%