MECH 573: Mechanics of Robotic Systems

Winter 2006: TR 11:35-12:55 ENGTR 1090
Instructor: Prof. Hamid D. Taghirad
McConnell Eng. Bldg. Room 423
Office Hours: Tuesdays 14:00 – 15:00

In this course the kinematics, dynamics analysis and control of robot manipulators is studied in detail. A review of kinematics analysis of serial manipulators, which is detailed in the prerequisite course MECH 572: Introduction to Robotics is presented here with an addition topic of screw and wrench representations. The main emphasis of the course is the mechanics of complex structured robots such as parallel manipulators. Comprehensive kinematics and dynamic analysis of parallel manipulators is presented, and the control topologies for these robots are described. In a comprehensive design project the students learn how to analyze the kinematics and dynamics of a planar parallel manipulator.

The tentative course program is as following:

Time:	**Teaching Contents**
Week 1:	**Introduction:** Kinematic chains, Grubler criterion, loop mobility criterion, robot classifications, description of position and orientation, screw-axis representation, Euler angle representations.
Week 2:	**Kinematics:** Review on position analysis of serial manipulators, Denavit Hartenberg convention, loop closure equations, kinematic analysis or 3R manipulator, successive screws, Elbow robot.
Week 3, 4:	**Kinematics:** Inverse Kinematics of General 6R manipulator. (By Jorge Angeles)
Week 5:	**Kinematics:** Kinematics analysis of parallel manipulators, vector loop equations, 3RRR manipulator, spatial orientation manipulator and Stewart Gough manipulator.
Week 6:	**Jacobian:** Angular and linear velocity, Jacobian matrices, Singularity conditions, conventional Jacobians, 3RRR manipulator, spatial orientation manipulator and Stewart Gough manipulator, Screw-based Jacobians.
Week 7:	**Stiffness:** Force-moment relations, principle of virtual work, 3RRR manipulator, stiffness analysis of parallel manipulators, stiffness analysis of Stewart-Gough platform.
	Midterm Exam
Week 8:	**Dynamics:** Dynamics analysis of parallel manipulators, Newton-Euler formulation, dynamic analysis of Stewart-Gough platform.
Week 9:	**Dynamics:** dynamics analysis of parallel manipulators, Principle of virtual work, Lagrange formulation, dynamic analysis of CKCM Robot.
Week 10:	**Control:** Introduction to control of parallel manipulators, position control topologies, inverse dynamics control.
Week 11:	**Control**: Robust inverse dynamics control, Force control topologies stiffness control.
Week 12:	**Control:** Force control topologies: Direct force control, impedance control.

Textbooks and References:

1 Lung-Wen Tsai, “Robot analysis: the mechanics of serial and parallel manipulators”, New York, Wiley, 1999. (Available at Bookstore)
2 Jorge Angeles, “Fundamentals of robotic mechanical systems: theory, methods, and algorithms”, New York, Springer, third edition 2006. (A printed version can be purchased from Irene)
3 M. W. Spong, S. Hutchinson, M. Vidyasagar**,** “Robot Modeling and Control”, New York, Wiley, November 2005.
4 L. Sciavicco, B. Siciliano, “Modelling and Control of Robot Manipulators” , Springer Verlag 2nd ed. 2001
5 J.P. Merlet, “Parallel robots”, Boston, MA : Kluwer Academic Publishers, 2000.
6 Carl Crane, “Screw theory for spatial robot manipulators”, Cambridge, Oxford, 2005.
7 John J. Craig, “Introduction to robotics: mechanics and control”, Mass., Addison-Wesley, 1989.
8 Frank Lewis, “Robot manipulator control : theory and practice”, New York : Marcel Dekker, 2004.
9 Selected papers.

Marking Scheme:

1. Assignments:	20%
2. Mid-term Exam:	40%
3. Term Project:	40%