**San Jose State University Department of Mechanical Engineering**

**ME 192 Robotics And Manufacturing Systems**

**Fall 2014**

**Course Description**

Scientific and engineering principles of robotics in the area of mechanical manipulation, dynamics, sensing, actuation, control, computer vision and manufacturing automation application. Motor, motion control, digital control devices application and integration.

**Instructor** Hee Man Bae, Ph.D.

 *Office hours* MW 4:00-5:45 p.m., Eng. 192  *E-mail*  hee.bae@sjsu.edu

# **Course Code and Class Hours**

ME192-01, 43951 Seminar MW 6:00-6:50 p.m., Eng. 192

 43952 Lab W 7:00-9:45 p.m., Eng. 192

**Prerequisites:** ME 106, ME 130 with C or better grade in each

# **Textbook** John J. Craig, Introduction to Robotics: Mechanics and Control, 3rd Edition, Prentice Hall, 2005. ISBN 0-201-54361-3

**Learning Objective**

*Upon successful completion of the course, the students will be able to:*

* Identify various robot configurations and make a best fit selection for on-hand application.
* Mathematically express the kinematics of the robot joint motion and the gripper placement.
* Specify the force and torque needed for the desired velocity and acceleration of the end-effector.
* Control robot arm movement manually or with program, following planned end-effector trajectory.
* Implement robot vision application with hands-on knowledge gained in the subject.
* Participate in robot system integration projects with exposure to most control and support devices.

**Lecture Topics**

*Aspects of both theoretical basis of robot joint movement and practical industry application are covered:*

* History and types of industrial robots, their application, and analytical framework - Introduction
* The mathematics of robot joint motion that governs the manipulator arm motion – Kinematics.
* Multi-link transformation of joint angular velocities into Cartesian velocities – Jacobian Matrices
* Motion control including angular velocity and acceleration of joints, force and torque – Dynamics
* End-effector trajectory generation with polynomial smoothing – Path Generation
* Programming, teach/program path generation, joint-Cartesian frame conversion – Hands-on
* Image transformation, morphology, pattern recognition, vision guided operation – Robot Vision

**Lab Projects**

*Lab projects bolster the class room learning and the students gain hands-on experience as a team.*

* Robot Frame Description – Cartesian, SCARA, and 6-Axis robots
* Forward Kinematics – Transformation matrices for 6-Axis, SCARA, and Cartesian
* Arm Manipulation - Control, V+ Programming, joint-Cartesian transformation, pick & place
* Robot Vision - Vision command, geometric pattern test, image recognition, vision guided P&P
* Term project – Composite design application using the knowledge gained. Joint transformation, robot motion control, arm trajectory, gripper and camera offset, with or without vision guide.

**Grading Scheme**

Midterm Exams 1 and 2 (15% each) 30 %

Final Exam 20 %

Term Project 20%

Lab Reports 15 %

Homework assignments and quizzes 15 %

Letter Grades (*Assigned upon normalization*):

 A+ 95-100 A 90-94.9 A- 87-89.9%

 B+ 85-86.9 B 80-84.9 B- 77-79.9%

 C+ 75-76.9 C 70-74.9 C- 67-69.9%

 D+ 65-66.9 D 60-64.9 D- 57-59.9%

 F Below 57

**Academic Integrity**

All students must maintain high ethical standards in pursuing their course work in regard to tests, homework, lab projects, report writing, etc. Cheating during exams, plagiarism, or blatant copying of other’s homework or lab projects will result in zero credit and, as appropriate, will be reported to the Office of Student Conduct and Ethical Development. The university policy concerning academic integrity may be found in *http//www2.sjsu.edu/senate/S04-12.pdf*.

**Campus Policy on Disabilities**

Presidential Directive 97-03 requires that students with disabilities requiring accommodations must register with the Disability Resource Center (DRC) at: www.drc.sjsu.edu.

**Class Conduct, Rules, and Expectations**

***Pertaining to Seminars***

*Class notes:* Selected lecture notes, lab instructions, and partial answers to homework and exams will be posted in the course website or emailed to the students before or after the use of the materials in the class.

*Distractions:* Cell phone use, internet browsing, and food and drink are not allowed during lecture period and at any place in the equipment area.

*Email:* Electronic submission of homework will require instructor’s prior consent. Lab reports may be submitted electronically, but a hard copy is still required.

*Attendance:* Attendance will not be checked except the first two weeks of the term. However the lab attendance is mandatory to receive a team credit.

*Exams:*  All exams are closed book. The two midterm exams may consist of two parts – in-class and take-home. The in-class part will have a variety of problems not requiring extensive calculations. You may bring one 8.5”x11” sheet of paper containing equations, tables, etc. The take-home part will have time consuming proofs and calculations. Each exam will be preceded by an in-class work session.

# *Homework and Quizzes:*  Home work will be assigned mostly on Wednesday on each chapter. It will be collected at the beginning of the class the following Monday. Two people may collaborate in answering the questions. A group copying of a home work will result in a zero credit. Not all assignments will be collected. Instead, a pop quiz may be given for a random check.

***Pertaining to Lab***

*Team Work*: The lab projects are carried out in teams of 3-4 person. The team members are expected to attend all lab sessions and participate in all team activities. Each team will keep an activity log sheet. The instructor may solicit team feedback regarding member participation. The project grade that a team member will receive may partially reflect the level of his/her contribution.

*Project Duration*: 2 weeks each for Project 1-4 and 5 weeks for Project 5 (term project).

# *Programming*: Any robot programs worked on during lab hours must be saved on a team’s flashy memory. The instructor will purge any team programs left on a PC or robot controller.

*Reports*: Lab reports are due on the first lecture session following successful project completion. The report must contain a cover sheet, general project description, any program listing with comments, any drawings and methods used, and a team activity log sheet. Submit a hard copy of the report to the instructor or an ME secretary and a soft copy to the instructor as a duplicate.

*Safety:* Adhere to the safety rules laid out by the instructor along with a good judgment. Never execute a motion program if the robot gripper can strike a person nearby. Leave all cable connections and wiring changes with the instructor or the lab assistant. Never exceed the speed limit of the manipulator arm specified by the instructor. If a robot arm moves faster than a person can react, the speed is set too high. Sign the Safety Rules agreement form before taking on any lab project.

*Extra Lab Hours:* The lab will be open for project work during the instructor’s office hours. In other times, a special arrangement may be made with the instructor or the assistant to have the lab open. Out of safety concerns, the robots may not be turned on without the presence of supervision.

*Special Term Project:* Students who wish to take on a special project individually in lieu of the term project may do so with an instructor’s permit. The project may be job related, but the most of the work needs to be done in the lab.

**Seminar Schedule**

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| --- | --- | --- | --- |
| ***Week*** | ***Date*** | ***Topics*** | ***Reading Assign.*** |
| 1 | 8/258/27 | Orientation. Robot history and types.Spatial Description – Rotation & Translation | Ch. 1 (1.1-1.3)Ch. 2 (2.2-2.4) |
| 2 | 9/19/3 | Labor Day RecessCoordinate Transformation | Ch. 2 (2.5-2.7) |
| 3 | 9/89/10 | Ch. 2 Problem SolvingManipulator Kinematics | Ch. 3 (3.2-3.4) |
| 4 | 9/159/17 | Forward KinematicsCh. 3 Problem Solving | Ch. 3 (3.5-3.7) |
| 5 | 9/229/24 | Review for Exam #1**Exam 1 (Ch. 2, 3)** |  |
| 6 | 9/2910/1 | Inverse KinematicsClosed Form Solutions | Ch. 4 (4.2-4.5) Ch. 4 (4.6) |
| 7 | 10/610/8 | Ch. 4 Problem SolvingLinear & Rotational Velocities of Robot Links | Ch. 5 (5.1-5.4) |
| 8 | 10/1310/15 | Velocity Propagation Ch. 5 Problem Solving | Ch. 5 (5.5-5.6) |
| 9 | 10/2010/22 | Jacobians & Singularities Static Force Domain | Ch. 5 (5.7-5.8)Ch. 5 (5.9-5.11) |
| 10 | 10/2710/29 | Review for Exam #2**Exam #2 (Ch. 4, 5)**  |  |
| 11 | 11/311/5 | Manipulator Dynamics, Newton’s and Euler’s EquationsIterative Newton-Euler and Lagrangian Formulations | Ch. 6 (6.2-6.4)Ch. 6 (6.5-6.8) |
| 12 | 11/1011/12 | Ch. 6 Problem SolvingTrajectory Generation using Cubic Polynomials | Ch. 7 (7.1-7.3) |
| 13 | 11/1711/19 | Trajectory Generation using Parabolic BlendsMachine Vision – Erosion/Dilation, Shape/Pattern Recognition | Ch. 7 (7.3)Handout |
| 14 | 11/2411/26 | Machine Vision – Calibration, Image Rotation & Translation Thanksgiving Recess |  |
| 15 | 12/112/3 | Ch. 7 and Machine Vision Problem SolvingCourse Review & Term Project Work |  |
| 16 | 12/812/10 | Final Exam ReviewTerm Project Presentation and Demonstration |  |
| 17 | **12/15** | **Final Exam(Ch. 6, 7, Machine Vision)** *5:15 – 7:30 p.m., Eng. 192.* |  |

**Lab Schedule**

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| --- | --- | --- | --- |
| ***Week*** | ***Dates*** | ***Proj.*** | ***Topics*** |
| 1 | 8/27 |  | Video – Intro. to Robotics. Lab tour - Power up, program commands, Adept vision |
| 2 | 9/3 | Lab 1 | Robot Frame Description – Cartesian, SCARA, and 6-Axis. |
| 3 | 9/10 |  |  |
| 4 | 9/17 | Lab 2 | Forward Kinematics – Transformation matrices for 6-Axis, SCARA, and Cartesian |
| 5 | 9/24 |  |  |
| 6 | 10/1 | Lab 3 | Manual control, V+ programming, Joint-Cartesian transformation, Delta positioning |
| 7 | 10/8 |  |  |
| 8 | 10/15 | Lab 4 | Vision Command, Geometric Pattern test, Image recognition, Vision guided P&P |
| 9 | 10/22 |  |  |
| 10 | 10/29 | Lab 5 | Term project – Team brain storming |
| 11 | 11/5 |  | Project proposal due |
| 12 | 11/12 |  |  |
| 13 | 11/19 |  | Interim report due |
| 14 | 11/26 |  |  Thanksgiving Recess |
| 15 | 12/3 |  |  |
| 16 | 12/10 |  | Team presentation & report submission. |

 *Updated – 8/15/14*