San Jose State University Department of Mechanical Engineering
ME 192 Robotics and Manufacturing Systems
Fall 2018

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Office Hours MW: 9:30-10:00 AM; M: 5:50-6:20 PM; W: 3:45-4:15 PM (E310F or E192)

Course Code & Schedule

ME192 Section 1 (Seminar, by Dr. Du) 47397	MW 12:00-12:50, E192
ME192 Section 2 (Lab, by Dr. Hee Man Bae) 47398	M 13:30-16:15, E192

Prerequisites ME 106, ME 130 with C- or better in each

Course Description

Scientific and engineering principles of industrial (serial) robots/manipulators. Homogenous transformation, robot kinematics, statics, dynamics, Jacobin, trajectories, control and programming. Lab experiments to support the lectures, verify the theories taught, and provide the students with hands-on robot operation, control (both computer and manual), and programming experiences and skills. Robot design, sensing (especially machine vision system), actuation, and applications. Other types of robots and applications.

Textbook *Introduction to Robotics:* 1st Edition by Winncy Du
Robotics Lab Manual: 1st Edition by Hee Man Bae

Grading Scheme

Homework	10%
Midterm Exams 1 and 2 (10% each)	20%
Final Exam	20%
Lab Experiments & Reports	21 %
Term Project	19 %
Lab Quiz and Programming	10%

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:	< 57

Learning Objective

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

- Know the history and types of industrial robots and their applications
- Distinguish various robots' configurations (Cartesian, SCARA, Articulated, Cylindrical, Spherical, and Parallel) and their workspace
- Describe a homogenous transformation matrix and its meaning for a robot joint
- Perform joint-to-joint transformations to find the end-effector's position and orientation
- Mathematically express the kinematics and dynamics of a robot
- Calculate the force or torque required at each joint in order for a robot to move with the desired velocity and acceleration
- Find the Jacobian of a robot
- Understand and describe a robot's workspace and singularity
- Derive robot dynamics equation using both Newton-Euler's law and Lagrangian methods
- Describe the dynamic equation of a robot in a state-space form
- Control an industrial robot both manually or automatically (through a computer program)
- Design a robot's trajectory with the desired velocity, acceleration, and via points.
- Write a code using Matlab, ACE, and V+ programming tools to control and simulate an industry robot.
- Know how to use a virtual lab to control robots.

Tentative Seminar Schedule

WEEK #	**TOPICS**
Week #1 08/22	Course syllabus, pre-requisites, permit codes; course overview and structure
Week #2 08/27, 08/29	Ch.1 Robotics History, Types, and Applications Ch.2 Robotics Terminologies, Configurations, and Workspace
Week #3 09/05	Ch.3 Homogenous Transformation Matrix and Robot Link/Human Arm Descriptions
Week #4 09/10, 09/12	Ch.4a Coordinate Transformation Ch.4b Denavit-Hartenberg Convention to Assign Frames to Links
Week #5 09/17, 09/19	Ch.5a Manipulator/Human Limb Forward Kinematics Ch. 5b: Implementation of Forward Kinematics through Matlab
Week #6 09/24, 09/26	Ch.6a Inverse Kinematics: Closed-form Solution Ch.6b Inverse Kinematics: Piper's Solution
Week #7 10/01, 10/03	Term Project Information & Guideline Inverse Kinematics Exercise on An Articulated Robot
Week #8 10/08, 10/10	Review for Exam #1 **Exam 1 (Ch.1-6)**
Week #9 10/15, 10/17	Ch.7 Velocity "Propagation" from Link to Link Ch.8 Cartesian Transformation of Velocities and Static Forces
Week #10 10/22, 10/24	Ch. 9 Jacobians and Singularities Ch.10a Manipulator Dynamics: Newton's and Euler's Equations
Week #11 10/29, 10/31	Ch.10b Iterative Newton-Euler and Lagrangian Formulations Ch.11 Forming Manipulator/Limb Dynamics in Cartesian Space
Week #12 11/05, 11/07	Derivation of a Robot Dynamic Equation Using Iterative Newton-Euler Method Invited Speaker
Week #13 11/14	Review for Exam #2 **Exam #2** (Ch.7-11)
Week #14 11/19	Ch.12a Trajectory Generation: Cubic Polynomials Cubic Trajectory Description Using MATLAB
Week #15 11/26, 11/28	Ch.12b Trajectory Generation: Linear Function with Parabolic Blends Linear Function with Parabolic Blends Using MATLAB II
Week #16 12/03, 12/05	Course project presentation, demonstration, and evaluation
Week #17 12/10	Course Review
Final Exam Date: 9:45-12:00, Thursday, December 13, E192	

LAB INFORMATION

To enhance classroom learning and to provide the students hands-on experience in industrial robots.

- Using an Excel model, learn the robot positioning through multiplication of homogeneous transformation matrices incorporating the length, twist, and offset of each link and joint angle set.
- Using the ACE emulation software downloaded onto the student PC, experiment with life like movement of various robot configurations, and edit and debug the robot motion programs.
- Perform routine pick & place task and path control using teach pendant robot programming. Also, calculate the end effector offset using inverse transformation equation.
- Apply robot vision process to acquire capability in handling randomly placed moving objects. Also, learn to compute the position offset of the camera from the robot base or from the gripper Z axis.

Lab Demonstrations

- Matlab Robotics Toolbox to formulate and perform advanced kinematics calculations.
- More advanced robot types – collaborative robot and mobile robot - that are not in the lab.
- Examples of extended robot vision application.
- Tool changer and vacuum generator for end effectors.

Term Project

The term project will allow students to use the knowledge they learned from the lectures to solve a real world problem. For example, program or control an industry robot to perform a pick-and-place task, or use the same principles to create a prosthetic device, analyze an ankle's force/torque, compare load difference between standing, walking, and running. Another example is to use sensors and a microcontroller to make the robot end effector perform some complex tasks.

Class Conduct, Rules, and Expectations

Pertaining to Lectures

Attendance: Attendance in all lectures/labs is expected.

Homework: Homework will be assigned on Wednesday. It will be collected at the beginning of the class on the following Wednesday.

Pertaining to Lab

Teamwork: The lab experiments are carried out in teams of 3-4 students. The team members are expected to attend all lab sessions and participate in all team activities. The instructor may solicit team feedback regarding individual member participation. Unauthorized non-emergency absence will have an adverse effect on the grade one will receive.

Programming: Any robot program created during lab hours must be saved on the team's USB memory module. The instructor may erase any team programs left on a PC or a robot controller.

Reports: Reports must contain a cover sheet, the general description, the approach taken, the program code (if applicable) with comments, any helpful flowchart or a picture, and the summary. Submit a hard copy (for grading and feedback) two days from the completion of the lab exercise. A soft copy may be accepted with preapproval.

Safety: Adhere to the safety rules set by the lab instructor. Never execute a robot motion program if any part of a person is reachable by the robot arm. Leave all cable connections and wiring changes with the instructor. Do not exceed the speed limit of a robot specified by the instructor. **Read the *Safety Rules* and sign the agreement form prior to starting the first lab**.

Lab Activities and Grade Assignment

Hands-on lab exercises (3) - 21% weight on the course grade
- 2 week duration for each exercise
- Robot/robot vision programming and problem solving.
- 3-4 person teams. Members are randomly selected.

Term project - 19% weight on the course grade
- 6 week duration
- Team initiated projects with instructor assistance

- 3-4 person teams. The students select team members.

Mid-term Lab Quiz and Programming Test - 10% weight on the course grade
- Review and assessment of learning from the three preceding lab exercises

Demonstration of robotic tools and applications. The demo schedule may change from week to week.
- To introduce various robotic equipment and application software, not used in the lab exercises.
- To provide ideas for the term projects and potential tools for future robot applications.

Lab Schedule

Wk	*Dates*	*Subject*	*Contents*
1	8/27	Orient-ation	Introduction - Video viewing: History of industrial robot. Preparation - Download ACE, Excel kinematics model, Matlab Robotics Tool Box
2	9/10	Lab 1	Joint framing – Link twist & offset. 6-axis, SCARA, Cartesian. Use ACE & Excel.
3	9/17		*Demo 1– Conveyor tracking simulation on ACE using kinematics solution.*
4	9/24	Lab 2	Position & motion – Manual/program control, joint rotation, location transformation.
5	10/1		*Demo 2 – 7-axis Baxter collaborative robot manipulation (in A&T Lab).*
6	10/8	Lab 3	Robot vision - Geometric pattern test, camera calibration, vision guided pick & place.
7	10/15		*Demo 3 – Application of directional image scanning for edge detection*
8	10/22	Lab quiz Proj org.	Quiz on robot manipulation, program commands, and vision processing. Term project – Team organization, and topic selection.
9	10/29	wk 1	Team design brain storming. Project proposal due.
10	11/5	wk 2	*Demo 4 – Omron-Adept Intelligent mobile robot (in A&T Lab).*
11	11/19	wk 3	Interim report due. *Demo 5– Belt tracking & object-in-motion picking operation*
12	11/26	wk 4	*Demo 6 – Use of tool changer and vacuum generator*
13	12/3	wk 5	Report preparation
14	12/10	wk 6	Team presentation & report submission.

LAB EXPERIMENTS

Lab 1 – Robot joint frames & Arm manipulation

Instruction – Robot configurations, identification of joint type & link parameters (link length, link twist, and Link offset), rotational vs. linear motion. Use of Excel model for robot kinematics and location transformation. ACE software download.

Demo – Arm manipulation with teach pendant, E-stop, jam recovery, monitor commands for location definition and joint motion. Safe pick & place routine.

Exercise – Manipulate the robot arm with teach pendant in both joint and Cartesian motion. Find the gripper angle w.r.t. the robot base given the joint angles and the arm link twists. Move the joints by set values and compare the gripper position change with the Excel model. Extract homogeneous transformation matrix from the nine element location vector. Practice READY, HERE, MOVE, and DRIVE commands.

Lab 2 – Robot pick & place motion and V^+ program commands

Instruction – V^+ program commands, SEE and ACE editors, Adept's on-line language/user/reference manuals. Location definition in Cartesian and joint frames. Relationship between relative positioning and transformation equation.

Demo – ACE emulation for tracking and picking randomly placed object on constant speed conveyor belt based on inverse Jacobian solution.de

Exercise – Define locations and set up coded transformation equation. Write a command sequence for pickup & drop-off operation. Use loops for repeat motion and position indexing. Learn program read-write commands, signal I/O commands, and protocols for file transfer. Set up an inverse transformation equation to find the gripper offset.

Lab 3 - Robot Vision

Instruction – Robot vision processing sequence and common terminology used. ADC of pixel image and successive approximation method used in 8-digit quantization. Threshold for binary conversion. Image filters. Area of Interest, morphology operation (erosion and dilation) and edge extraction.

Demo **-** Pallet bar code read using edge detection tool 4-digit quantization. Extraction of the perimeters of color images via linear scanning (as an alternative to extraction via morphology operation).

Exercise – Learn Adept vision commands: AOI, WINDOW, MORPH, PICTURE, LOCATE. Learn about vision attributes. Perform a geometric test for object identification. Set up an inverse transformation equation to find the camera offset.

Term Project

To be qualified, the term project must meet the following conditions:

a. Not directly related to the senior design project of any of the team members.
b. Not be in the expertise area of any of the team members.
c. Not work related to any of the team members.
d. A common interest and fresh learning to all members.
e. Most of the design work can be done in the lab during the lab hours. Attendance will be checked.
f. The project is scoped is for six week duration with defined deliverables. A proposal will be required.

Academic Integrity

Your commitment as a student to learning is evidenced by your enrollment at San Jose State University. The University's Academic Integrity policy, located at http:// www.sjsu.edu/senate/S07-2.htm, requires you to be honest in all your academic course work. Faculty members are required to report all infractions to the office of Student Conduct and Ethical Development. The Student Conduct and Ethical Development website is available at http://www.sjsu.edu/studentconduct/. Instances of academic dishonesty will not be tolerated. Cheating on exams or plagiarism (presenting the work of another as your own, or the use of another person's ideas without giving proper credit) will result in a failing grade and sanctions by the University. For this class, all HW assignments are to be completed by the individual student unless otherwise specified.

Campus Policy in Compliance with the American Disabilities Act

If you need course adaptations or accommodations because of a disability, or if you need to make special arrangements in case the building must be evacuated, please make an appointment with me as soon as possible, or see me during office hours. Presidential Directive 97-03 requires that students with disabilities requesting accommodations must register with the Disability Resource Center (DRC) at http://www.drc.sjsu.edu/ to establish a record of their disability.

Student Technology Resources

Computer labs for student use are available in the Academic Success Center located on the 1st floor of Clark Hall and on the 2nd floor of the Student Union. Additional computer labs in Mechanical Engineering Department are located in E213/215. Computers are also available in the Martin Luther King Library. A wide variety of audio-visual equipment is available for student checkout from Media Services located in IRC 112. These items include digital and VHS camcorders, VHS and Beta video players, 16 mm, slide, overhead, DVD, CD, and audiotape players, sound systems, wireless microphones, projection screens and monitors.

Learning Assistance Resource Center

The Learning Assistance Resource Center (LARC) is located in Room 600 in the Student Services Center. It is designed to assist students in the development of their full academic potential and to inspire them to become independent learners. The Center's tutors are trained and nationally certified by the College Reading and Learning Association (CRLA). They provide content-based tutoring in many lower division courses (some upper division) as well as writing and study skills assistance. Small group, individual, and drop-in tutoring are available. Please visit the LARC website for more information at http://www.sjsu.edu/larc/.

SJSU Writing Center

The SJSU Writing Center is located in Room 126 in Clark Hall. It is staffed by professional instructors and upper-division or graduate-level writing specialists from each of the seven SJSU colleges. Our writing specialists have met a rigorous GPA requirement, and they are well trained to assist all students at all levels within all disciplines to become better writers. The Writing Center website is located at http://www.sjsu.edu/writingcenter/about/staff/.

Peer Mentor Center

The Peer Mentor Center is located on the 1st floor of Clark Hall in the Academic Success Center. The Peer Mentor Center is staffed with Peer Mentors who excel in helping students manage university life, tackling problems that range from academic challenges to interpersonal struggles. On the road to graduation, Peer Mentors are navigators, offering "roadside assistance" to peers who feel a bit lost or simply need help mapping out the locations of campus resources. Peer Mentor services are free and available on a drop –in basis, no reservation required. The Peer Mentor Center website is located at http://www.sjsu.edu/muse/peermentor/

Student Success and Wellness

Attending to your wellness is critical to your success at SJSU. I strongly encourage you to take advantage of the workshops and programs offered through various Student Affairs Departments on campus such as Counseling Services, the SJSU Student Health Center/ Wellness & Health Promotion Dept., and Career Center. See http://www.sjsu.edu/ wellness or http://www.sjsu.edu/counseling/Workshops/ for workshop/events schedule and links to many other services on campus that support your wellness! You may go to http://events.sjsu.edu to register for any one of the workshops.