San Jose State University Department of Mechanical Engineering  
ME 192 Robotics and Manufacturing Systems  
Fall 2022  

Lecture Instructor  Dr. Lin Jiang, 408-924-4596; lin.jiang@sjsu.edu; Office: E310C  
Office Hours  M: 16:30-17:30; W: 13:30-14:30 or by email appointment  
Lab Instructor  Aaron Zhao; Yirong.zhao@sjsu.edu; Office: E192B  

Course Code & Schedule  
ME192 Section 1 (Seminar, 46899) MW 12:00-12:50, E192  
ME192 Section 2 (Lab, 46900) M 13:30-16:15, E192  
ME192 Section 3 (Lab, 47668) M 9:00-11:45, 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  
Robotics Lab Manuals: To be posted on Canvas  

Grading Scheme  
Homework  20%  
Midterm Exam  20%  
Final Exam  20%  
Hands-on Lab Exercises  20 %  
Term Project  15 %  
Lab Quizzes  5%  

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 each 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  
- 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 and 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.

**Late Policy:** Unless otherwise specified for a particular assignment, work that is submitted late will be accepted with reduced credit accordingly:

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<tr>
<th>Homework</th>
<th>Midterm &amp; Final Exam</th>
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<tbody>
<tr>
<td>12 hours late</td>
<td>1 - 5 minutes late: -10%</td>
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<td>24 hours late</td>
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<td>36 hours late</td>
<td>11-15 minutes late: -50%</td>
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<td>37-48 hours late</td>
<td>Over 15 minutes late: -100%</td>
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**Exceptions:** Any grading appeals or petitions must be communicated promptly in writing (or email). Exceptions will normally be evaluated at the very end of the semester in context with overall semester track record and all other exceptions class-wide. Special consideration for truly unavoidable and extenuating circumstances will depend on timeliness and strength of supporting documentation (e.g., doctor's note, policereport, military orders).

**Course Requirements and Assignments**

According to the Office of Graduate and Undergraduate Programs [http://www.sjsu.edu/gup/syllabusinfo/](http://www.sjsu.edu/gup/syllabusinfo/), “Success in this course is based on the expectation that students will spend, for each unit of credit, a minimum of 45 hours over the length of the course (normally 3 hours per unit per week with 1 of the hours used for lecture) for instruction or preparation/studying or course related activities including but not limited to internships, labs, clinical practice. Other course structures will have equivalent workload expectations as described in the syllabus.”

- **Homework:** Homework problems are usually assigned on each Thursday and due by the midnight of the following Wednesday. They will be assigned corresponding to lecture topics. Some of the homework may be software-based. Students are encouraged to discuss general strategies collaboratively, but each student is expected to prepare and submit his or her own individual work. Your lowest HW grade will be dropped when calculating your final grade.

- **Midterm & Final Exams:** All students are expected to complete one midterm and one final exams in class as scheduled. Special accommodations for disabilities must be coordinated through the Accessible Education Center [http://www.sjsu.edu/aec/](http://www.sjsu.edu/aec/).

**Classroom Protocol**

Although University Policy F15-12 at [http://www.sjsu.edu/senate/docs/F15-12.pdf](http://www.sjsu.edu/senate/docs/F15-12.pdf) states that “Attendance shall not be used as a criterion for grading”, the policy also states, “Students are expected to attend all meetings for the courses in which they are enrolled as they are responsible for material discussed therein” and furthermore, “Participation may be used as a criterion for grading when the parameters and their evaluation are clearly defined in the course syllabus and the percentage of the overall grade is stated.”

**University Policies**

Per University Policy S16-9, university-wide policy information relevant to all courses, such as academic integrity, accommodations, etc. will be available on Office of Graduate and Undergraduate Programs’ Syllabus Information web page at [http://www.sjsu.edu/gup/syllabusinfo/](http://www.sjsu.edu/gup/syllabusinfo/)
<table>
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<tr>
<th>WEEK #</th>
<th>TOPICS</th>
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<tr>
<td>Week #1 08/22, 08/24</td>
<td>Course syllabus &amp; overview. Ch.1 Introduction</td>
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<tr>
<td>Week #2 08/29, 08/31</td>
<td>Ch.2 Robot Link Descriptions &amp; Homogenous Transformation Matrix</td>
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<td>Week #3 09/07</td>
<td>Ch.3a Denavit-Hartenberg Convention to Assign Frames to Links</td>
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<td>Week #4 09/12, 09/14</td>
<td>Ch.3b Manipulator Forward Kinematics Ch.3C Examples of Manipulator Forward Kinematics</td>
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<td>Week #5 09/19, 09/21</td>
<td>Ch.4a Manipulator Inverse Kinematics: Closed-form Solution</td>
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<td>Week #6 09/26, 09/28</td>
<td>Ch.4b Inverse Kinematics: Piper’s Solution</td>
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<td>Week #7 10/03, 10/05</td>
<td>Ch.5a Jacobians and Velocity</td>
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<td>Week #8 10/10, 10/12</td>
<td>Review for Midterm Exam (Ch.2-4); <strong>Midterm Exam</strong></td>
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<td>Week #9 10/17, 10/19</td>
<td>Ch.5b Velocity “Propagation” from Link to Link Ch. 5c Robots’ Singularities</td>
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<td>Ch.5c Static Forces</td>
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<td>Week #11 10/31, 11/02</td>
<td>Ch.6a Manipulator Dynamics: Newton’s and Euler’s Equations</td>
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<td>Week #12 11/07, 11/09</td>
<td>Ch.6b Iterative Newton-Euler Formulation for Manipulators’ Motion Equations</td>
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<td>Week #13 11/14, 11/16</td>
<td>Ch.6c Lagrangian Formulation for Manipulators’ Motion Equations</td>
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<td>Week #14 11/21</td>
<td>Ch.7a Trajectory Generation: Cubic Polynomials and MATLAB</td>
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<td>Week #15 11/28, 11/30</td>
<td>Ch.7b Trajectory Generation: Linear Function with Parabolic Blends</td>
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<td>Week #16 12/05</td>
<td>Course Review for Final Exam (Ch.5-7)</td>
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**Final Exam Time, Date, and Location:** 12:00-13:00, Wednesday, December 07, E192
ME 192 Robotics and Manufacturing Systems Laboratory

Fall 2022

Lab Exercises

To enhance classroom learning and to provide the students hands-on experience in industrial robots. The students are divided into three-member teams. The lab exercise includes:

- Using an Excel model, learn robot positioning through a series of homogeneous transformation matrices incorporating the reach, twist, and offsetting of each link and joint angle.
- Using the ACE emulation software, experiment with real time movement of robot arm, and learn to program and debug the robot motion.
- Perform routine pick & place task and path control using teach pendant. Also, calculate the end effector offset using inverse transformation equation.
- Apply robot vision process to track and pick randomly placed stationary or moving objects. Also, learn to determine the camera position offset from the gripper or the robot base.
- Experience teleoperation and haptic feedback in robot control.
- Lab exercise description: Students will be divided into two groups (Group A and Group B) in each lab section on the first week of lab. While one of the Group is working on Lab activities in E192, the other group will asynchronously work on lab theory posted on Canvas.

Term Project

The following restrictions in selecting and carrying out a term project applies to the term projects that are considered as an outgrowth of one or more of the lab exercises. An instructors’ permit is required to take on a special project that is considered as a research and development work in nature which is beyond the scope of a term project.

The qualification of the term project is as follows:

a) The project is for ME192 only, not in conjunction with any other course such as senior design course.
b) The project is not work related for any team member. It is a common interest to the team members.
c) Most of the project work, excluding part fabrication, can be done in the lab using the available robots.
d) If executed properly, the project plan will yield tangible results in a four-week period during which no prescribed lab exercises will be conducted.

Lab Conduct, Rules, and Expectations

Teamwork: The lab exercises are done in teams of three 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. Unapproved non-emergency absence will result in a zero credit for the missed lab session. However, there will be a make-up session toward the end of the term. Those who want to make up for a missed lab will meet with the instructor for a special assignment. An emergency or medical absence will receive a full lab credit for the lab.

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, a general description, the approach taken, any program code with comments, any helpful flowchart or a picture, and a summary. Submit a hard copy (for grading and feedback) two days from the second week of each lab. 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 (4) - 20% weight on the course grade
- 2-week duration for each exercise
- Manual, programmed, and vision assisted arm manipulation.
- 3-person teams. Random team assignment with exceptions.

Lab quizzes (2) - 5% weight
- Robot arm kinematics and manipulation.
- Gripper offset and camera offset. Robot vision processing.

Term project (1) - 15% weight
- 4-week duration following 2-week planning period.
- Team initiated projects with instructor assistance
- 3-person teams. The students form teams.

Demonstration of robotic tools and applications
- To introduce various robotic equipment and application software, not covered in the lab exercises.
- To provide tips for term project ideas and use of special tools.

**Lab Exercise – General Description**

**Lab 1: Introduction to Robots**

a) Industrial Robot types and configurations
b) Robot applications
c) Software interface to control Robots: MATLAB, V+, etc.
d) Robot coordinate systems (World-, Joint-, and tool-coordinates)
e) Robot’s controller, driver, amplifiers
f) Robot control using a teaching pedant

**Lab 2: Robot’s Forward Kinematics and Programming using ACE**

a) Robot Programming Software and Emulation
b) Adept ACE programming environment
c) V+ learning
d) Writing a simple program to move a robot on emulation.
e) Understand the different coordination systems in the emulation program.
f) Setting up a coordinate system to each joint of a robot
g) Measure a robot’s parameters (link length, twist angle, offset, or joint angle)
h) Establish a Denavit-Hartenberg table for the given robot
i) Derive a 4x4 transformation matrix for each joint
j) Find the robot’s forward kinematics using excel kinematics model or MATLAB model

**Lab 3: Robot Motion Control Using a computer**

a) Write a robot’s pick-and-place program with the position indexing and the gripper offset
b) Calculate the transformation needed in order to place a robot’s end-effector in a desired position and orientation
c) Input the transformation into the programming code
d) Demonstrate (using emulation) the robot is placed and orientated in the desired position and direction with the transformation code
e) Write and run the V+ program on ACE, and transfer program file to robots.
f) Debug and Troubleshoot the V+ program
g) Run the pick and place motion with the robots.

**Lab 4: Robotic Control with Digital I/O**

a) Use the robot’s controller’s digital output ports to turn on indications
b) Design a circuit (or use a pre-designed circuit) integrated with the robot controller
c) Control the robots with external sensors via digital input & output ports
d) Read three different inputs from toggle switches.
e) Direct the robot to a distinct location depending on button pressed.
f) Indicate location by turning on appropriate indicator lamp.

**Lab 5: Introduction to Machine Vision**

a) Vision system basics (lens, imaging, lens equation, focal length, depth of field, illuminators)
b) Pixels, image, resolutions, aspect ratio, image processing and transformation
c) Object description and recognition
Lab 6: Introduction to Teleoperation and Haptic Feedback in Robot Control

a) Understand the basics of Haptic feedback
b) Learn TCP/IP communication using microcontrollers
c) Link the haptic robot with the articulated robot
d) Control the articulated Denso robot with Haptic robot
e) Apply noise reduction to the trajectory control

ME192 Course Projects

Term Projects (Pick one)

- Project 1: Robot Control with the Machine Vision Feedback
- Project 2: Robot Control with the Convey Belt Moving
- Project 3: Soft/Vacuum Pneumatic Grippers for Pick and Place
- Project 4: Haptics Feedback with Robot Control
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