E T 7995
Industrial Robots Dynamics and Control

Course Description:
The direct and inverse dynamic problem for industrial robots. Newton-Euler and
Lagrange-Euler equations of robot arm motion. A new automatic separation method
(ASM) for automatic generation of dynamic equations. Robot trajectory generation.
Control of Robot Manipulators (PID control, design of control systems in State-Space and
computed torque technique). Sensing (range sensing, proximity sensing, touch sensing,
force and torque sensing). Current Trends and Research in Industrial Robotics.

Credit Hours: 4

Prerequisites: N/A

Co requisites: N/A

Textbook Other Required Materials:
1. Introduction to Robotics: Mechanics and Control, John J. Craig, 3rd edn, Pearson
   Education, Harlow, 2004
2. In addition there will be handout notes available on Blackboard.
3. The lecture material will be supplemented using the referred list of texts.

References:
1. Robotics: control, sensing, vision, and intelligence, Fu K. S., Gonzalez R.C., and Lee
4. Mechanisms and robots analysis with Matlab, 2009
5. Workspace 5@User Manual.
**Tentative Topics:**

1. Jacobian: Definition of the Jacobian, singularities, velocities and static forces. Examples: selected industrial robots. [chapter 5]
2. Introduction to Manipulator Dynamics. Linear and angular acceleration of a rigid body. Mass distribution. [chapter 6]
6. Trajectory generation (general considerations, path description and generation, joint and Cartesian space shames). [chapter 7]
7. Linear control of robot manipulators (PID and design of control systems in State-Space). [chapter 9]
8. Control of Robot Manipulators (computed torque technique). [chapter 11]
9. Sensing (range sensing, proximity sensing, touch sensing, force and torque sensing).

**Grading Policy:**

The breakdown of the marks is:

- A. Homework Assignments to be issued regularly: 30%
- B. Written Exam: 30%
- C. Individual Final Project (presentation and report): 40%

Total: 100%

<table>
<thead>
<tr>
<th>Letter Grade</th>
<th>- Modifier</th>
<th>Unmodified</th>
<th>+ Modifier</th>
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<tbody>
<tr>
<td>A</td>
<td>90 - 93</td>
<td>94+</td>
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<tr>
<td>B</td>
<td>80 - 82</td>
<td>83 - 86</td>
<td>87 - 89</td>
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<tr>
<td>C</td>
<td>70 - 72</td>
<td>73 - 76</td>
<td>77 - 79</td>
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<tr>
<td>D</td>
<td>60 - 62</td>
<td>63 - 66</td>
<td>67 -69</td>
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<td>F</td>
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<td>59 or less</td>
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<td>I</td>
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<td>Incomplete Work</td>
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<td>WP</td>
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<td>Withdraw (Passing at time of withdrawal)</td>
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<td>WF</td>
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<td>Withdraw (Failing at time of withdrawal)</td>
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<td>WN</td>
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<td>Withdraw (Never showed or no basis for grade)</td>
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- Graduate students must receive C or better to pass this course, and maintain an overall minimum 3.00 GPA (B) to remain in good standing
- Grading scales for graduate students are listed on WSU Graduate Level Scholarship: [http://gradschool.wayne.edu/current/scholarship.php](http://gradschool.wayne.edu/current/scholarship.php)
- Graduate and undergraduate students will have different requirements as listed in the following table:
<table>
<thead>
<tr>
<th>Workload</th>
<th>Undergraduate</th>
<th>Graduate</th>
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</thead>
<tbody>
<tr>
<td>Assignment #2</td>
<td>Selection and mathematical modeling of DC motors and sensors. Select 6 motors and sensors.</td>
<td>Selection and mathematical modeling of DC motors and sensors. Select 10 motors and sensors.</td>
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<tr>
<td>Assignment #3</td>
<td>5 questions related to the Control Theory.</td>
<td>6 questions related to the Control Theory.</td>
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<tr>
<td>Written Exam</td>
<td>5 questions on: comprehensive written exam.</td>
<td>6 questions on: comprehensive written exam.</td>
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<tr>
<td>Final Project</td>
<td>Dynamic and Control modeling and simulation of selected robot including the motors. Use Maple 17 and Matlab.</td>
<td>Dynamic and Control modeling and simulation of selected robot including the motors and load. Use Maple 17 and Matlab.</td>
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✓ No late homework will be accepted, as solution will be handed out on the day the homework is due.
✓ A written report will be required for the lab project
✓ All exams are open-books and notes
✓ Exam dates can be moved forward or back on meeting day by class vote

Course Learning Objectives:

Upon completion of this course, students should be able to:
1. Perform mathematical analysis of objects position and orientation in space using homogeneous coordinates and composite homogeneous transformation matrix. [SOa, SOb, SOd, M1]
2. Mathematical modeling of robot kinematic structure using Denavit-Hartenberg representation. [SOa, SOb, SOd, SOf, M1]
3. Solving the direct kinematic problem for multi DOF kinematic structures with different type of joints, using composite homogeneous transformation matrix. [SOa, SOb, SOd, SOf, M1]
4. Solving the inverse kinematic problem using analytical and geometric approaches applied for 2DOF, 3DOF, 4DOF, 5DOF, and 6DOF manipulators. [SOa, SOb, SOd, SOf, M1]
5. Use different methods to calculate the Jacobian, singularities, velocities and static forces for multi DOF kinematic structures. [SOa, SOb, SOd, SOf, M1]
6. Apply computer simulation and off-line programming software, such as Workspace LT, to model robots and mechanisms (rotary tables, conveyers, tools, etc.) for different applications in manufacturing systems. [SOa, SOb, SOd, SOf, M1, M3]
7. Evaluate safety issues for robot workspace layout design (collision detection, path generation, robot Workenvelope generation, etc.). [SOa, SOb, SOd, SOf, M1, M3]
8. Communicate effectively in oral and written formats [SOg]

Contributions to MIT Program Student Outcomes:

<table>
<thead>
<tr>
<th>Level</th>
<th>BSMIT Program Student Outcome</th>
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<tr>
<td>3</td>
<td>a. an ability to select and apply the knowledge, techniques, skills, and modern tools of their disciplines to broadly-defined engineering technology activities</td>
</tr>
<tr>
<td>3</td>
<td>b. an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies</td>
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</tbody>
</table>
c. an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes

d. an ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives

e. an ability to function effectively as a member or leader on a technical team

f. an ability to identify, analyze, and solve broadly-defined engineering technology problems

g. an ability to communicate effectively regarding broadly-defined engineering technology activities

h. an understanding of the need for and an ability to engage in self-directed continuing professional development

i. an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity

j. a knowledge of the impact of engineering technology solutions in a societal and global context

k. a commitment to quality, timeliness, and continuous improvement

M1 – MCT Design Track: Students in this track will demonstrate the ability to apply principles of materials and mechanics to the design and analysis of mechanical components and mechanisms.

M2 – MCT Energy Track: Students in this track will demonstrate the ability to apply principles of thermo-fluid sciences to the design and analysis of energy systems

M3 – MCT Manufacturing Track: Students in this track will demonstrate the ability to apply principles of materials and production techniques to the planning, implementation, and control of manufacturing processes

University / Division Policies:
Academic Misconduct
http://www.et.eng.wayne.edu/et/academicmisconduct/academicmisconduct.html
Withdrawal from Engineering Tech class
http://www.et.eng.wayne.edu/withdraw/withdraw.html
Deferred Grades
http://www.et.eng.wayne.edu/et/deferredgrade/deferredgrade.html

Code of Ethics for Engineers:
http://cems.alfred.edu/courses/ces120/ethics/abet.html
http://cems.alfred.edu/courses/ces120/ethics/ieee.html
http://onlineethics.org/codes/
http://www.iit.edu/departments/csep/codes/coe/abet-a.html

Prepared by: Ana Djuric