

# MECH 464, Industrial Robotics

(3 Credits)

## Course Structure

3 hours of lecture per week, T/Th 9:30-11, MCLD 220.

## Course Grading (approximate scheme only)

Lab	20 %
Midterm	30 %
Final Exam	50 %
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	100 %

## Instructor

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## Course Text

Mark W. Spong, Seth Hutchinson and M. Vidyasagar, *Robot Modeling and Control*, John Wiley and Sons, 2006.

## Course Website

Course information is posted on VISTA – [www.vista.ubc.ca](http://www.vista.ubc.ca). If you are registered in the course you should be able to access the course materials.

Course notes are available on the website. Bring the notes to class - they are indispensable.

## References

### 1. Books

- a) Sciavicco, L. and Siciliano, B., *Modeling and Control of Robot Manipulators*, McGraw Hill, New York, 2<sup>nd</sup> Ed, Springer-Verlag, 2000.
- b) S. B. Niku, *Introduction to Robotics, Analysis, Systems, Applications*, Prentice Hall, 2001.
- c) R.L. Andersson, *A Robotic Ping-Pong Player - Experiment in Real-Time Intelligent Control*, MIT Press, 1988.
- d) J. Angeles, *Spatial Kinematic Chains: Analysis, Synthesis and Optimization*, Springer Verlag, 1982
- e) H. Asada and J.J. Slotine, *Robot Analysis and Control*, Wiley-Interscience, 1986.
- f) J.J. Craig, *Introduction to Robotics: Mechanics and Controls, Second Ed.*, Addison Wesley, 1989.
- g) C.W. de Silva, *Control, Sensors and Actuators*, Prentice Hall, 1989.
- h) K.S. Fu, R.C. Gonzalez, C.S. Lee, *Robotics: Control, Sensing, Vision, Intelligence*, McGraw-Hill, 1987.

- i) J.M. McCarthy, *An Introduction to Theoretical Kinematics*, MIT Press, 1991
- j) R.P. Paul, *Robot Manipulators: Mathematics, Programming and Control*, MIT Press, 1981.
- k) G. Strang, *Linear Algebra and Its Applications*, Second Ed. Academic Press, 1980. (or your favorite linear algebra text)
- l) S.G. Tzafestas, Ed., *Intelligent Robotic Systems*, Marcel Decker Inc., 1991.
- m) T. Yoshikawa, *Foundations of Robotics - Analysis and Control*, MIT Press, 1990.
- n) V. Daniel Hunt, *Robotics Sourcebook*, Elsevier, 1988.

## 2. Journals

- a) ASME Journal of Dynamic Systems, Measurement and Control
- b) Robotics and Autonomous Systems, Elsevier.
- c) Robotica, Cambridge University Press.
- d) Journal of Robotic Systems, John Wiley and Sons
- e) International Journal of Robotics Research, MIT Press
- f) IEEE Transactions on Robotics
- g) IEEE Transactions on Systems Man and Cybernetics

## 3. Software

- a) Matlab – Student edition is fine.
- b) Robotics Toolbox for Matlab by Peter I. Corke. See course website for the link to download this free toolbox.

## Tentative Course Outline

## Approx. # of hours

1. Introduction to Robotics	1 Hour
1.1 What does a robot look like?	
1.2 What do robots do?	
1.3 Robot Manipulators	
1.4 Some of the Research Issues involving Robotic Manipulators	
1.5 Robots and Industry	
2. Rigid Motions	2 Hours
2.1 Review of Linear Algebra. Notations and Definitions.	
2.2 Frames and Rotations	
2.3 Basic Rotations	
2.4 Composition of Rotations	
2.5 More 'Fun' Properties of Rotation Matrices - The Axis-Angle Representation	
2.6 Homogeneous Transformations	
2.7 Basic Homogeneous Transformations	
2.8 Exercises	
3. Forward Kinematics	2 Hours
3.1 Kinematic Chains	

3.2 The Devanit Hartenberg Convention	
3.3 Exercises	
4. Inverse Kinematics	2 Hours
4.1 Overview	
4.2 Algebraic Solution	
4.3 Geometric Solution	
4.4 Numerical Solution	
4.5 Summary	
4.6 Exercises	
5. Differential Kinematics	4 Hours
5.1 Differentiation of Rotation Matrices	
5.2 Velocity and Acceleration Kinematics	
5.3 The Manipulator Jacobian	
5.4 Geometric Formulation of the Jacobian	
5.5 Formulation of the Jacobian by Differentiation	
5.6 The General Jacobian Formulation	
5.7 Kinematic Singularities	
5.8 Redundancy	
5.9 Exercises	
6. Manipulator Statics	2 Hours
6.1 Forces and Torques	
6.2 The Principle of Virtual Work	
6.3 The Generalized Statics Relationship	
6.4 The Stiffness/Compliance Matrix	
6.4 Exercises	
7. Manipulator Dynamics	5 Hours
7.1 Hamilton's Principle	
7.2 Derivation of Lagrange's Equations from Hamilton's Principle	
7.3 Lagrange's Equations of Motion: Examples	
7.4 Formulation for Kinetic Energy for a N-Link Manipulator	
7.5 Generalized Equations of Motion for a N-Link Manipulator	
7.6 Example: Two-Link Planar Robot	
7.7 Christoffel Symbols	
7.8 The Recursive Newton Euler Formulation	
7.9 Direct and Inverse Dynamics	
7.10 Acceleration Directions	
7.11 Exercises	
8. Path and Trajectory Planning	3 Hours
8.1 Definitions	
8.2 Joint-Space Trajectories	
8.3 Work-Space Trajectories	
8.4 Optimal Motion Planning	
8.5 Obstacle Avoidance	
8.6 Exercises	

9. Computer Vision	4 Hours
9.1 Image Processing Fundamentals	
9.2 Image Acquisition	
9.3 Frame Grabbing	
9.4 Image Formation	
9.5 Camera Calibration	
9.6 Introduction to Visual Servoing	
10. Robot Motion Control	3 Hours
10.1 The Control Problem	
10.2 Actuator Dynamics	
10.3 PD Compensation	
10.4 PID Compensation	
10.5 Inverse Dynamics Compensation	
10.6 Exercises	
11. Interaction Control	2 Hours
11.1 Single Degree of Freedom Stiffness Control	
11.2 Inverse Dynamics in Task Space	
11.3 Impedance control	
11.4 Exercises	
12. Project presentation	3-4 Hours

## LAB

The lab outline will be posted on VISTA in October. The lab involves implementing a sensor driven task on an industrial robot. The lab will be scheduled for 3 hours in November. Lab team size and number of labs slots TBA.

There are no marked assignments for the course. However, there are assignments given with each chapter of the notes and solutions will be posted.

## MIDTERM

**October 22. Closed book.** Formula sheet provided.

**FINAL EXAM:** The final exam is scheduled by the university. It will be a closed book exam covering the complete course. The invigilators will not answer any questions regarding material on the exam, during the exam period.

**All exams are CLOSED BOOK.**