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**ENG ME/SE740: Vision, Robotics, and Planning—Intelligent Machines**

Course Outline: (Spring 2019)

1. Foundations of intelligent mechatronics
2. Geometry and robot coordinate systems
  - (i) Rigid motions of  $\mathbb{R}^3$
  - (ii) Kinematic pairs and the lattice of subgroups of the special Euclidean group
  - (iii) Free vectors and bound vectors
3. Euclidean group theory and kinematic equations
  - (i) The Denavit-Hartenberg formalism
  - (ii) The product of exponentials formula
  - (iii) Screw theory
4. Differential relationships
  - (i) The manipulator Jacobian for spatial mechanisms
  - (ii) The propagation of joint velocities and forces
5. Specifying robot motions
  - (i) The theory of motion interpolation
  - (ii) Nonholonomic motion planning
6. Analytical dynamics of mechanical systems
  - (i) Lagrangian mechanics
  - (ii) Hamiltonian mechanics
7. Control: basic issues
  - (i) Controllability
  - (ii) Design and synthesis
  - (iii) Stability of feedback control laws
8. Control: information-based control
  - (i) Nyquist frequency and Shannon's theorem
  - (ii) The zero order hold and quantization alternatives
  - (iii) The data-rate theorem and feedback control with communications constraints
9. Advanced topics: algebraic and geometric methods
  - (i) Nonlinear/geometric control theory
  - (ii) Motion control in living organisms: paradigms and puzzles
  - (iii) Networked control systems
  - (iv) Graph theoretic structures for distributed control and control motifs
10. Advanced topics: cooperative control
  - (i) Control of multiple mobile agents
  - (ii) Data-structures for distributed control of mobile agents
  - (iii) Distributed sensing and sensor fusion
  - (iv) The *blind robot problem*
11. Advanced topics: information-based control theory
  - (i) Connecting control theory to information theory
  - (ii) Information gradients
  - (iii) Optimal reconnaissance strategies

(iv) *Control communication complexity*

## 12. Advanced topics: kinematic redundancy

- (i) Survey of techniques for resolving kinematic redundancy
- (ii) The extended Jacobian technique and constrained motions
- (iii) Super-articulated mechanical systems

## Suggested Reading

Text:

Richard M. Murray, Zexiang Li, S. Shankar Sastry, *A Mathematical Introduction to ROBOTIC MANIPULATION*, CRC Press, Boca Raton, 1994.

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<a href="#">Abebooks (used)</a>	\$78.84	<a href="#">eCampus (new)</a>	\$76.71

Other books:

→Recommended:

Bloch, J. Baillieul, P.E. Crouch & J.E. Marsden, *Nonholonomic Mechanics and Control*, Springer-Verlag, Interdisciplinary Applied Mathematics, ISBN:0-387-95535-6, 483 pages.

Kumar, N. Leonard, & A.S. Morse (Eds.), *Cooperative Control*, Springer Lecture Notes in Control and Information Sciences, V. 309, Springer-Verlag, Berlin Heidelberg, ISBN 3-540-22861-6, 2005.

→Suggested further reading:

J. Baillieul, Shankar Sastry, and Hector J. Sussmann (Editors), *Essays on Mathematical Robotics*, (IMA Volumes in Mathematics and Its Applications, V. 104.), Springer Verlag; ISBN: 0387985964, 1998.

J. Baillieul & J.C. Willems (Editors), *Mathematical Control Theory*, Hardcover - 385 pages, Springer Verlag; ISBN: 0387983171, 1998.

Brockett, R.W., ed., *Robotics*, Proceedings of Symposia in Applied Mathematics, Vol. 41, American Math. Soc., Providence,

1990.

Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, & Giuseppe Oriolo, *Robotics: Modelling, Planning and Control*, Springer, 1st edition, New York, ISBN-10: 1846286417, ISBN-13: 978-1846286414, Dec., 2008.

John J. Craig, *Introduction to Robotics: Mechanics and Control*, 3rd Ed., Prentice Hall 2004.

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

Francesco Bullo, Jorge Cortes, Sonia Martinez, *Distributed Control of Robotic Networks: A Mathematical Approach to Motion Coordination Algorithms*, (Princeton Series in Applied Mathematics), Princeton University Press, July 6, 2009, 336 pages, ISBN-10: 0691141959, ISBN-13: 978-0691141954.

Kevin Lynch and Frank Park, *Modern Robotics: Mechanics, Planning, and Control*, Cambridge University Press, 2017, 642 pages, ISBN-13: 978-1107156302, ISBN-10: 1107156300.

Available for free download at <http://hades.mech.northwestern.edu/images/7/7f/MR.pdf>.

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## Grading

Grades will be given for homework assignments (one every week or so), class participation, and most importantly, for a term project which will be assigned during the first few weeks of the class.

The instructors for Spring 2018: Professor J. Baillieul, [johnb@bu.edu](mailto:johnb@bu.edu) and Professor T. Djaferis, [ted1@bu.edu](mailto:ted1@bu.edu).

For continually updated information about the class, visit: [Robotics](#).

Updated: 1/21/19)