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ENG ME 740: **Vision, Robotics, and Planning—Intelligent Machines**

Course Outline: (Spring 2018)

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 volicities 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 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. (Ordering information to be given in class.)

Other books:

A.M. 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.

V. 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.

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.

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, ISBN-13: 978-1107156302, ISBN-10: 1107156300.

$\longrightarrow$Available for free download at `http://hades.mech.northwestern.edu/images/7/7f/MR.pdf`

Instructors and 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 and Professor T. Djaferis, ted1@bu.edu.

For up-to-date information about the class, visit: http://people.bu.edu/johnb/ME740.html.

(1/11/18)