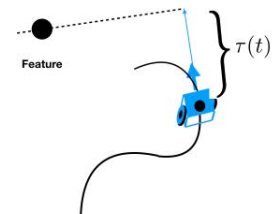
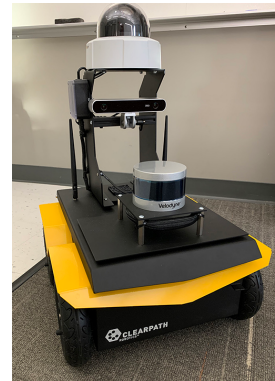


ENG ME 740: **Vision, Robotics, and Planning—Intelligent Machines**

Course Outline: (Spring 2021)

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*



Time-to-transit is one of many optical cues in vision-guided navigation: See "Perceptual Control with Large Feature and Actuator Networks" <https://arXiv.org/abs/1903.10259>.

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. ISBN: 0849379814

Kevin M. Lynch, Frank C. Park, *Modern Robotics: Mechanics, Planning, and Control*, Cambridge University Press; 2017. ISBN: 1107156300

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

(Ordering information for both books is on the class web site: <http://www.baillieul.org/Robotics>.)

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.

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.

For up-to-date information about the class, visit: <http://www.baillieul.org/Robotics>.

(1/11/21)