

Todd D. Murphey

Mechanical Engineering
Northwestern University
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EDUCATION

California Institute of Technology

Pasadena, CA

- Ph.D. in Control and Dynamical Systems, 2002
- Thesis: *Control of Multiple Model Systems*

University of Arizona

Tucson, AZ

- B.S. in Mathematics, *summa cum laude*, 1997

EMPLOYMENT

Northwestern University	<i>Assistant Professor</i>	2009-present	Evanston, IL
University of Colorado at Boulder	<i>Assistant Professor</i>	2004-2008	Boulder, CO
Aerospace Corporation	<i>Senior Technical Staff</i>	2003-2004	El Segundo, CA
Northwestern University	<i>Postdoctoral Scholar</i>	2002-2003	Evanston, IL

AWARDS AND HONORS

- Participant in National Academy of Engineering Frontiers of Engineering Education Symposium
- Searle Fellow at Northwestern University (2009-2010)
- Bruce Holland Excellence in Teaching award (2007) (awarded by ECE Department at CU Boulder)
- National Science Foundation CAREER award (2006)

PUBLICATIONS, ¹ SOFTWARE, AND INVITED TALKS

Books

- [1] G. S. Chirikjian, H. M. Choset, M. A. Morales, and T. D. Murphey, eds., *Algorithmic Foundation of Robotics*. Springer Tracts in Advanced Robotics, Springer-Verlag, 2009.

Journal Articles

- [12] E. Johnson and T. D. Murphey, "Second-order switching time optimization for nonlinear time-varying dynamic systems," *SIAM Journal on Control and Optimization*, To be Submitted.

¹Reprints of many of these can be found at <http://robotics.mech.northwestern.edu/~murphey>

- [11] T. Caldwell and T. D. Murphey, "Switching mode generation and optimal estimation with application to skid-steering," *Automatica*, Submitted.
- [10] P. Martin, E. Johnson, T. D. Murphey, and M. Egerstedt, "Constructing and implementing motion programs for robotic marionettes," *IEEE Transactions on Robotics*, 2008. Submitted.
- [9] T. D. Murphey and J. Falcon, "Programming from the ground up in controls laboratories using graphical programming," *International Journal of Engineering Education*, Accepted for Publication.
- [8] E. Johnson and T. D. Murphey, "Scalable variational integrators for constrained mechanical systems in generalized coordinates," *IEEE Transactions on Robotics*, In Press.
- [7] B. Shucker, T. D. Murphey, and J. Bennett, "Convergence preserving switching for topology-dependent decentralized systems," *IEEE Transactions on Robotics*, vol. 24, pp. 1405–1415, Dec. 2008.
- [6] T. D. Murphey and K. M. Lynch, "Case studies in planar part feeding and assembly based on design of limit sets," *International Journal of Robotics Research*, vol. 27, pp. 693–708, June 2008.
- [5] T. D. Murphey, "Teaching rigid body mechanics using student-created virtual environments," *IEEE Transactions on Education*, vol. 51, no. 1, pp. 45–52, 2008.
- [4] T. D. Murphey, "On multiple model control for multiple contact systems," *Automatica*, vol. 44, pp. 451–458, 2008.
- [3] T. D. Murphey, "Kinematic reductions for uncertain mechanical contact," *Robotica*, vol. 25, pp. 751–764, Nov 2007.
- [2] T. D. Murphey and J. W. Burdick, "The power dissipation method and kinematic reducibility of multiple model robotic systems," *IEEE Transactions on Robotics*, vol. 22, pp. 694–710, August 2006.
- [1] T. D. Murphey and J. W. Burdick, "Feedback control for distributed manipulation with changing contacts," *International Journal of Robotics Research*, vol. 23, pp. 763–782, July 2004.

Refereed Book Chapters

- [6] E. Johnson, K. Morris, and T. D. Murphey, *Algorithmic Foundations of Robotics VIII*, ch. A Variational Approach to Strand-Based Modeling of the Human Hand. Springer-Verlag, 2008. Eds. G. Chirikjian, H. Choset, M. Morales, T. Murphey.
- [5] T. D. Murphey, *Algorithmic Foundations of Robotics VII*, ch. Mechanical Manipulation Using Reduced Models of Uncertainty, pp. 359–374. Springer-Verlag, 2008. Eds. S. Akella, N. Amato, W. Huang, B. Mishra.
- [4] M. Egerstedt, T. D. Murphey, and J. Ludwig, *Hybrid Systems: Computation and Control*, vol. TBD of *Lecture Notes in Computer Science*, ch. Motion Programs for Puppet Choreography and Control, pp. 190–202. Springer-Verlag, 2007. Eds. A. Bemporad, A. Bicchi, and G. C. Buttazzo.
- [3] T. D. Murphey, *Multi-point Interaction with Real and Virtual Objects*, ch. On Observing Contact States in Overconstrained Manipulation, pp. 151–164. Springer-Verlag, 2005. Eds. F. Barbagli, D. Prattichizzo, and K. Salisbury.
- [2] T. D. Murphey and J. W. Burdick, *Algorithmic Foundations of Robotics V*, ch. Feedback Control for Distributed Manipulation, pp. 487–503. Springer-Verlag, 2004. Eds. J. D. Boissonnat, J. Burdick, K. Goldberg, and S. Hutchinson.

- [1] K. M. Lynch and T. D. Murphey, *Control Problems in Robotics and Automation*, ch. Control Issues in Nonprehensile Manipulation, pp. 39–57. Springer-Verlag, 2003. Eds. A. Bicchi and H. Christensen.

Refereed Conference Papers

- [33] E. Johnson and T. D. Murphey, “Second order switching time optimization for time-varying nonlinear systems,” in *IEEE Int. Conf. on Decision and Control*, 2009.
- [32] V. Seghete and T. D. Murphey, “Multiple instantaneous collisions in a variational framework,” in *IEEE Int. Conf. on Decision and Control*, 2009.
- [31] E. Johnson and T. D. Murphey, “Automated trajectory morphing for marionettes using trajectory optimization,” in *IEEE Int. Conf. on Automation Science and Engineering*, 2009.
- [30] T. Caldwell and T. D. Murphey, “Second-order optimal estimation of slip state for a simple slip-steered vehicle,” in *IEEE Int. Conf. on Automation Science and Engineering*, 2009.
- [29] E. Johnson and T. D. Murphey, “Dangers of two-point holonomic constraints for variational integrators,” in *American Controls Conference (ACC)*, 2008.
- [28] K. Nichols and T. D. Murphey, “Variational integrators for constrained cables,” in *IEEE Int. Conf. on Automation Science and Engineering (CASE)*, pp. 802–807, 2008.
- [27] T. D. Murphey, “Filtering of interaction rules in cooperation,” in *American Controls Conference (ACC)*, pp. 3733–3739, 2008.
- [26] M. Travers, T. D. Murphey, and L. Pao, “Data association with ambiguous measurements,” in *American Controls Conference (ACC)*, pp. 1875–1880, 2008.
- [25] E. Johnson and T. D. Murphey, “Discrete and continuous mechanics for tree representations of mechanical systems,” in *IEEE Int. Conf. on Robotics and Automation*, pp. 1106–1111, 2008.
- [24] T. D. Murphey and M. Horowitz, “Adaptive cooperative manipulation with intermittent contact,” in *IEEE Int. Conf. on Robotics and Automation*, pp. 1483–1488, 2008.
- [23] T. D. Murphey and M. E. Egerstedt, “Choreography for marionettes: Imitation, planning, and control,” in *IEEE Int. Conf. on Intelligent Robots and Systems Workshop on Art and Robotics*, p. 6 pages, 2007.
- [22] T. D. Murphey, “Geometric derived information spaces in manipulation with mechanical contact,” in *IEEE Int. Conf. on Automation Science and Engineering (CASE)*, pp. 338–345, 2007.
- [21] E. Johnson and T. D. Murphey, “Dynamic modeling and motion planning for marionettes: Rigid bodies articulated by massless strings,” in *IEEE Int. Conf. on Robotics and Automation*, pp. 330–335, 2007.
- [20] T. D. Murphey, “Teaching rigid body mechanics using student-created virtual environments,” in *American Controls Conference (ACC)*, pp. 2503–2508, 2007.
- [19] B. Shucker, T. D. Murphey, and J. Bennett, “Switching rules for decentralized control with simple control laws,” in *American Controls Conference (ACC)*, pp. 1485–1492, 2007.
- [18] T. D. Murphey and J. Falcon, “Programming from the ground up in controls laboratories using graphical programming,” in *Proceedings of the IFAC Advances in Control Education (ACE)*, p. 6 pages, 2006.
- [17] T. D. Murphey, “Modeling and control of multiple-contact manipulation without modeling friction,” in *Proc. American Controls Conference (ACC)*, pp. 3227–3234, 2006.

- [16] B. Shucker, T. D. Murphey, and J. Bennett, "Switching control without nearest neighbor rules," in *Proc. American Controls Conference (ACC)*, pp. 5959–5965, 2006.
- [15] T. D. Murphey, "Motion planning for kinematically overconstrained vehicles using feedback primitives," in *Proc. IEEE Int. Conf. on Robotics and Automation*, pp. 1643–1648, 2006.
- [14] B. Shucker, T. D. Murphey, and J. Bennett, "Cooperative control using occasional non-local interactions," in *Proc. IEEE Int. Conf. on Robotics and Automation*, pp. 1324–1329, 2006.
- [13] T. D. Murphey, J. Bernheisel, D. Choi, and K. M. Lynch, "An example of parts handling and self-assembly using stable limit sets," in *Proc. of International Conference on Intelligent Robots and Systems (IROS)*, pp. 1624–1629, 2005.
- [12] T. D. Murphey, "Application of supervisory control methods to uncertain multiple model systems," in *Proc. American Controls Conference (ACC)*, vol. 2, pp. 774–780, 2005.
- [11] T. D. Murphey, D. Choi, J. Bernheisel, and K. M. Lynch, "Experiments in the use of stable limits sets for parts handling," in *Proc. Int. Conf. MEMS, NANO, and Smart Systems (ICMENS)*, (Banff, Canada), pp. 218–224, 2004.
- [10] T. D. Murphey and J. W. Burdick, "Kinematic reducibility for multiple model systems," in *Proc. IEEE Conf. on Decision and Control (CDC)*, vol. 5, (Maui, Hawaii), pp. 5307–5313, 2003.
- [9] T. D. Murphey and J. W. Burdick, "Experiments in nonsmooth control of distributed manipulation," in *IEEE Int. Conf. on Robotics and Automation*, pp. 3600–3606, 2003.
- [8] T. D. Murphey and J. W. Burdick, "Smooth feedback control algorithms for fully actuated distributed manipulators," in *IEEE Int. Conf. on Robotics and Automation*, pp. 3619–3623, 2003.
- [7] T. D. Murphey and J. W. Burdick, "Nonsmooth controllability theory and an example," in *Proc. IEEE Conf. on Decision and Control (CDC)*, (Las Vegas), pp. 370–376, 2002.
- [6] T. D. Murphey and J. W. Burdick, "Global exponential stabilizability for distributed manipulation," in *Proc. IEEE Int. Conf. on Robotics and Automation*, (Washington D.C.), pp. 1210–1216, 2002.
- [5] T. D. Murphey and J. W. Burdick, "A local controllability test for nonlinear multiple model systems," in *Proc. American Controls Conference (ACC)*, vol. 6, (Anchorage, Alaska), pp. 4657–4661, 2002.
- [4] T. D. Murphey and J. W. Burdick, "Global stability for distributed systems with changing contact states," in *Proc. IEEE Int. Conf. on Intelligent Robots and Systems*, (Hawaii), pp. 214–219, 2001.
- [3] T. D. Murphey and J. W. Burdick, "A controllability test and motion planning primitives for overconstrained vehicles," in *Proc. IEEE Int. Conf. on Robotics and Automation*, (Seoul, Korea), pp. 2716–2722, 2001.
- [2] T. D. Murphey and J. W. Burdick, "On the stability and design of distributed systems," in *Proc. IEEE Int. Conf. on Robotics and Automation*, (Seoul, Korea), pp. 2686–2691, 2001.
- [1] T. D. Murphey and J. W. Burdick, "Issues in controllability and motion planning for overconstrained wheeled vehicles," in *Proc. Int. Conf. Math. Theory of Networks and Systems (MTNS)*, (Perpignan, France), p. 8 pages, 2000.

Publicly Available Software

- [1] E. Johnson and T.D. Murphey. The `trep` environment is a computation package for constrained mechanical systems. Currently, two packages are available for `trep`: (1) variational integrator; and (2) continuous dynamics. The `trep` environment is available at <http://trep.sourceforge.net>.

Invited Talks

- [24] Variational Methods for Hand Analysis and Simulation
Rehabilitation Institute of Chicago, August 2009.
- [23] OpenSTORM: Toward Robust Simulation in Manufacturing
RSS Workshop on Algorithmic Automation, June 2009.
- [22] Tree-Based Representations of Variational Integrators
Structured Integrator Workshop, May 2009.
- [21] Automated Marionettes and Control of Complex Mechanical Systems
University of Wyoming, October 2008.
- [20] Control Strategies for Manipulating String Puppets
AAAI Robotics Workshop: Creativity and Robotics, Chicago, Illinois, July 2008.
- [19] Abstraction and the Role of Graphical Programming in Education and Research
American Controls Conference Special Session on Low Cost and Embedded Control Technology for Mobile Applications, Seattle, WA, June 2008.
- [18] Reducing Complexity in Grasping Descriptions
ICRA Workshop on Dexterous Human Grasping, Pasadena, California, May 2008.
- [17] Variational Integrators for Mechanical Contact
ICRA Workshop on Modeling Contact in Manipulation and Locomotion, Pasadena, California, May 2008.
- [16] Numerical Optimization in Part Design
ICRA Workshop on Automated Assembly, Pasadena, California, May 2008.
- [15] Scalable Analysis and Simulation: From Simple Manipulation to String Puppets and Human Rehabilitation
Northwestern University, Evanston, Illinois, March 2008.
- [14] Geometric Methods for Dynamically Complex Manipulation Planning and Control
Carnegie Mellon University, Pittsburgh, PA, Spring 2008
- [13] Simple Representations of Contact for Manipulation
University of Southern California, Los Angeles, California, Nov 2007.
- [12] Marionettes as Complex Mechanical Systems
IROS Workshop on Art and Robots, San Diego, California, Nov 2007.
- [11] Automatic Synthesis of Motion Imitation In Marionettes
Northwestern University, Evanston, Illinois, May 2007.
- [10] Reduction of Information Requirements in Mechanical Systems
University of Illinois, Urbana-Champaign, Urbana-Champaign, Illinois, October 2006.
- [9] Hybrid Control in Manipulation and Coordination
Rice University, Houston, Texas, August 2006.
- [8] Innovative Teaching Methods with LabVIEW in Dynamic Systems and Controls (with Raul Longoria) *NI Week, Austin, Texas, August 2006.*
- [7] Abstraction and Uncertainty in Manipulation with Frictional Interfaces
Georgia Institute of Technology, Atlanta, Georgia, February 2006.

- [6] Manipulation, Puppets, and Forums *and*
Programming from the Ground Up in Control Classes Using LabVIEW
National Instruments Headquarters, Austin, Texas, January 2006.
- [5] Geometric Modeling and Control of Friction-Dominated Mechanical Systems
The University of Colorado, Boulder, Applied Mathematics Seminar, October 2005.
- [4] Modeling and Control of Friction-Dominated Mechanical Systems
The University of Pisa, Italy, April 2005.
- [3] On Observing Contact States in Overconstrained Manipulation
Workshop on Multi-point Interaction in Robotics, New Orleans, April 2004.
- [2] Kinematic Reducibility for Multiple Model Systems
Courant Institute - New York University, November 2003.
- [1] Controllability and Reducibility for Nonsmooth Mechanical Systems
Louisiana Conference on Mathematical Control Theory, April 2003.

FUNDING

- Todd D. Murphey (PI, 50%) and Magnus Egerstedt (Co-PI, 50%). National Science Foundation–CreativeIT: *Collaborative Research: Major: Puppet Choreography and Automated Marionettes.* \$800,000.
- Magnus Egerstedt (Co-PI, 50%) and Todd D. Murphey (PI, 50%). National Science Foundation–Software for Real-World Systems: *Collaborative Proposal: Abstraction-Based Motion Programs for Complex, Interconnected Systems.* \$450,000.
- Lucy Y. Pao (PI, 50%) and Todd D. Murphey (Co-PI, 50%). Air Force Research Laboratory: *Data Association and Sensor Management Algorithms for Tracking Applications.* \$250,000.
- Todd D. Murphey. National Science Foundation–Alternative Learning Technology: *Assessment of Controls Laboratory.* \$24,591.
- Todd D. Murphey. National Science Foundation–Civil and Mechanical Systems: *CAREER: Planning and Control for Overconstrained Mechanisms.* \$400,000.
- Other support from Disney/Imagineering, the Aerospace Corporation, and the National Instruments Foundation in excess of \$70,000.

TEACHING

Northwestern University

2009-present, Evanston, IL

- Taught course: *Systems Dynamics, EA-3* (Spring 2009)
- Created and taught course: *Introduction to Optimal Control, ME 495* (Winter 2009)

University of Colorado

2004-2008, Boulder, CO

- Created and taught course: *Engineering Freshman Honors Colloquium: Everything and More–A History of Limits and the Development of Modern Calculus* (Spring 2008)
- Created and taught course: *Engineering Freshman Projects: Algorithms in Robotics, GEEN 1400* (Fall 2007, 2008)
- Created and taught course: *Introduction to Geometric Mechanics and Control ECEN 4028/5028* (Spring 2006)
- Created and taught course: *Robot Dynamics and Motion Planning ECEN 4028/5028* (Spring 2006)
- Taught course: *Control Systems Analysis ECEN 4138* (Fall 2005, 2006)

- Created and taught laboratory: *Control Systems Lab ECEN 4638* (Fall 2005, 2006, 2007, 2008)
- Created and taught course: *Robot Control ECEN 5438* (Spring 2005, 2007)

Northwestern University

2002-2003, Evanston, IL

- Co-taught course: *Geometry in Robotics* (Spring 2003)
- Taught seminar course: *Introduction to Hybrid Dynamical Systems* (Autumn 2002)

PROFESSIONAL ACTIVITIES

- Associate Editor for the journal *IEEE Transactions on Robotics* (2008-present)
- Associate Editor for the journal *Robotica* (2007-present)
- Publication Chair for the 2010 Conf. on Automation Science and Engineering (CASE)
- Participant in the National Science Foundation and Computing Community Consortium (CCC) *Workshop on Robotics in Manufacturing and Automation*
- Co-Organizer (with Greg Chirikjian, Howie Choset, and Marco Morales) of 2008 *Workshop on the Algorithmic Foundations of Robotics (WAFR)*
- Co-Chair (with Ken Goldberg, Jean-Paul Laumond, and Vijay Kumar) of CASE 2008 workshop: *Workshop on Algorithmic Automation*
- Co-Organizer (with Vijay Kumar) of ICRA 2008 workshop: *Contact Models for Manipulation and Locomotion*
- Co-Organizer (with Francisco Valero-Cuevas and Yoky Matsuoka) of ICRA 2008 workshop: *Is human-like dextrous manipulation within our robotic grasp?*
- Program committees
 - 2009 *Robotics: Science and Systems*
 - 2008 *Hybrid Systems: Computation and Control Workshop*
 - 2008 *Robotics: Science and Systems*
 - 2008 *IEEE International Conference on Robotics and Automation*
 - 2008 *IEEE Conference on Automation Science and Engineering*
 - 2007 *IEEE/RSJ International Conference on Intelligent Robots and Systems*
 - 2007 *International Conference on Advanced Robotics*
 - 2007 *International Conference on Networked Robots*
 - 2007 *IEEE International Conference on Robotics and Automation*
 - 2006 *IEEE/RSJ International Conference on Intelligent Robots and Systems*
 - 2006 *IEEE International Conference on Robotics and Automation*
 - 2005 *Robotics: Science and Systems*
 - 2005 *IEEE/RSJ International Conference on Intelligent Robots and Systems*
 - 2001 *IEEE/RSJ International Conference on Intelligent Robots and Systems*
- Member of IEEE Robotics and Automation Society chapter award committee
- National Science Foundation Panelist in 2006
- Member of IEEE Robotics and Automation Society Conference Review board in 2004

- Reviewer for several journals (International Journal of Robotics Research, IEEE Transactions on Automatic Control, IEEE Transactions on Robotics, Robotica, ASME Journal of Dynamic Systems, Measurement, and Control) and conferences (IEEE International Conference on Robotics and Automation, IEEE/RSJ International Conference on Intelligent Robots and Systems, IEEE Conference on Decision and Control, American Controls Conference)
- Member, IEEE and SIAM
- Industrial Consulting and Research Partnerships
 - Disney R&D and Imagineering
 - National Instruments