RAFAL GOEBEL

COORDINATES

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EDUCATION

UNIVERSITIES ATTENDED:

94-00 University of Washington, Seattle, WA, USA

92-93 Rutgers University, New Brunswick, NJ, USA

89-92, 93-94 Maria Curie Sklodowska University, Lublin, Poland

DEGREES:

Ph.D. 2000, Department of Mathematics, University of Washington, Seattle; advisor: R.T. Rockafellar, thesis: *Convexity, Convergence and Feedback in Optimal Control*

M.Sc. 1994, Institute of Mathematics, University of Maria Curie-Sklodowska, Lublin, Poland (graduated with highest honors); thesis: *On the Stability of an L^2-angle*

EMPLOYMENT

13- Associate Professor at the Department of Mathematics and Statistics, Loyola University Chicago

08-13 Assistant Professor at the Department of Mathematics and Statistics, Loyola University Chicago

05-07 Part-Time Lecturer at the Department of Mathematics, University of Washington

fall 05 Part-Time Researcher at the Department of Electrical and Computer Engineering, University of California, Santa Barbara

02-04 Post-Doctoral Fellow at the Department of Electrical and Computer Engineering, University of California, Santa Barbara

00-02 Post-Doctoral Fellow and Instructor at the Departments of Mathematics of University of British Columbia and Simon Fraser University, Vancouver, Canada

summer 98 Researcher at the International Institute for Applied Systems Analysis, Vienna, Austria (Young Scientist Summer Program)

94-00 Teaching and Research Assistant at the Department of Mathematics, University of Washington

GRANT AND OTHER SUPPORT

2010-2013 National Science Foundation research grant 1008602, with E.N. Barron and R.R. Jensen

summer 2012 Loyola University Summer Research Stipend

AWARDS AND HONORS

10 IEEE Control Systems Society, 2010 Control Systems Magazine Outstanding Paper Award

09 SIAM Activity Group on Control and Systems Theory Prize

winter 00 McFarlan Fellowship, Department of Mathematics, University of Washington

93-94 Scholarship of the Polish Ministry of Education

92-93 Ambassadorial Scholarship from Rotary International

TEACHING EXPERIENCE AND TRAINING

08-present Loyola University Chicago, Assistant and Associate Professor

experience includes: Elements of Calculus I, Calculus I, Elementary Number Theory, Multivariable Calculus, Ordinary Differential Equations, Introduction to Real Analysis I, Introduction to Complex Analysis, Nonlinear Systems and Elements of Control

05-07 University of Washington, Part-time Lecturer

experience includes: Calculus II (integral calculus), Calculus III (Taylor polynomials, multivariable calculus), Discrete Mathematical Modeling, Nonlinear Optimization (senior level course)

00-02 Simon Fraser University and University of British Columbia, Instructor

experience includes: Introductory Mathematics for Social & Management Sciences, Integral Calculus, Ordinary Differential Equations

94-99 University of Washington, Teaching Assistant and Instructor

experience includes: Teaching Assistant Training; Teaching Assistant for: calculus, upper level undergraduate and graduate optimization courses; Instructor for: Calculus I (differential calculus), Linear Optimization (senior level course); Tutor at Math Study Center

93-94 University of Maria Curie-Sklodowska

Teacher Education Program, including teaching elementary and high school mathematics classes

SERVICE TO THE UNIVERSITY

13-14	Co-organizer, Undergraduate Colloquium in Mathematical Sciences, funded by College of Arts and Sciences
12-present	Member, Engineering Study Group (to develop biomedical engineering program)
12-13	Co-organizer, Undergraduate Colloquium in Mathematical Sciences, funded by College of Arts and Sciences
12	Presidential Scholarship Competition — candidate interviews
12-present	Member, Faculty Development Review Committee
11-12	Co-organizer, Applications of Mathematics Colloquium Series, funded by College of Arts and Sciences
fall 11	Member and Chair, FTTT Selection Committee, Department of Mathematics and Statistics
11-12	Curriculum Committee, College of Arts and Sciences Academic Council
10-12	College of Arts and Sciences Academic Council
09	Computational Science multidisciplinary Ph.D. planning committee
09	Presidential Scholarship Competition — candidate interviews

SERVICE TO THE COMMUNITY

Associate Editor	Systems and Control Letters, 2011-present
	Annales Universitatis Mariae-Curie Skłodowska, Sectio A, 2012-present
organizer	minisymposium on *Variational Analysis in Dynamics and Control*, SIAM Conference on Control and Applications, San Diego 2013
	special session on *Variational Analysis, Control and Optimization*, Mathematical Congress of the Americas, Guanajuato, Mexico 2013; co-organizers: Geraldo Silva, Brazil and Javier Rosenblueth, Mexico.
	minisymposium on *Analysis of hybrid, measure-driven, and linear complementarity dynamical systems*, SIAM Conference on Control and Applications, Denver 2009
	session on *Variational and Convex Analysis Techniques for Problems Involving Dynamics*, International Symposium on Mathematical Programming, Chicago 2009
referee	Automatica, IEEE Transactions on Automatic Control, Journal of Convex Analysis, Journal of Mathematical Analysis and Applications, SIAM Journal on Control and Optimization, SIAM Journal on Optimization, Systems and Control Letters, International Journal of Robust and Nonlinear Control
reviewer	Mathematical Reviews, 2005-present

RESEARCH INTERESTS

convex analysis, set-valued analysis, nonsmooth analysis

control, optimal control, duality in control

dynamical systems, hybrid systems, stability and stabilization

optimization

CONFERENCE PARTICIPATION (WITH PRESENTATION)

13 upcoming: Mathematical Congress of the Americas, Guanajuato, Mexico

SIAM Conference on Control and its Applications, San Diego

12 Workshop "Around Viability Boundaries", Paris, France (local support by organizers)

Workshop on Variational and Optimal Control Problems on Unbounded Domains, Haifa, Israel (full support by organizers)

11 IEEE Conference on Decision and Control, Orlando, FL

Workshop on Stabilization of Dynamical Systems and Processes, Edinburgh, Scotland (full support by organizers)

Workshop on Computational and Analytical Mathematics, in honour of Jonathan Borweins 60th Birthday, Vancouver, BC

Recent Development on L^∞-Variational Problems and Associated Nonlinear Partial Differential Equation, Lexington, KY

10 IEEE Conference on Decision and Control, Atlanta, GA

Canadian Mathematical Society Winter Meeting, Vancouver, BC

Workshop on Hybrid Dynamic Systems, University of Waterloo, Canada

09 SIAM Conference on Control and its Applications, Denver, CO

International Symposium on Mathematical Programming, Chicago, IL

Winter Meeting of the Canadian Mathematical Society, Windsor, Canada

08 AMS Fall Central Section Meeting in Kalamazoo

American Control Conference, Seattle, WA: Robust Hybrid Control Systems workshop

07 West Coast Optimization Meetings, Seattle, WA and Kelowna, BC

IEEE Conference on Decision and Control, New Orleans, LA

06 IEEE Conference on Decision and Control, San Diego, CA: workshop on Robust Hybrid Systems: Theory and Applications

05 American Control Conference, Portland, OR

04 Southern California Nonlinear Control Workshop, Santa Barbara, CA

03 Louisiana Conference on Mathematical Control Theory, Baton Rouge

West Coast Optimization Meeting, Vancouver, Canada

02 West Coast Optimization Meeting, Seattle, WA

IEEE Conference on Decision and Control, Las Vegas, NV

01 SIAM Conference on Control and its Applications, San Diego, CA

99 West Coast Optimization Meeting, Seattle, WA

98 Workshop on Variational Analysis and Related Topics, Davis, CA

97 West Coast Optimization Meeting Seattle, WA

SELECTED RECENT SEMINAR PRESENTATIONS

13 *Hybrid Dynamics and Control*, Northwestern Institute on Complex Systems, Northwestern University

12 *Consensus, Continuum of Equilibria, and Set-Valued Lyapunov Functions*, Coordinated Science Lab, University of Illinois Urbana-Champaign

Consensus, Continuum of Equilibria, and Set-Valued Lyapunov Functions, Grenoble Images Parole Signal Automatique Lab, Grenoble, France

Consensus, Continuum of Equilibria, and Set-Valued Lyapunov Functions, Laboratory for Analysis and Architecture of Systems, Toulouse, France

Conjugacy of convex and saddle functions and its application to dissipativity properties of uncertain linear dynamical systems I, II, Analysis Seminar, Department of Mathematics and Statistics, Loyola University Chicago

Consensus, Continuum of Equilibria, and Set-Valued Lyapunov Functions, Center for Control, Dynamical Systems and Computation, University of California, Santa Barbara

The Linear-Convex Regulator: Introduction, Center for Control, Dynamical Systems, and Computation, University of California, Santa Barbara

11 *Some Self-Dual Operations on Convex Functions I, II*, Analysis Seminar, Department of Mathematics and Statistics, Loyola University Chicago

What is control theory and why some interesting algebraic problems arise there, Algebra Seminar, Department of Mathematics and Statistics, Loyola University Chicago

10 *Hybrid Inclusions: A Framework for Modeling and Analysis of Hybrid Dynamical Systems*, Colloquium, Department of Mathematics, Virginia Commonwealth University

Some Self-Dual Operations on Convex Functions, Analysis Seminar, Department of Mathematics, Virginia Commonwealth University

09 *Homogeneity and tangent cones in approximation of hybrid dynamical systems*, Coordinated Science Laboratory, University of Illinois Urbana-Champaign

Hybrid Inclusions: A Framework for Modeling and Analysis of Hybrid Dynamical Systems, Mathematical Sciences Seminar, Department of Mathematical Sciences, Stevens Institute of Technology

Hybrid inclusions: modeling and analysis of dynamical systems with continuous-time and discrete-time features, Applied Mathematics Colloquium, Department of Mathematics and Statistics, University of Maryland Baltimore County

The Linear-Convex Regulator, Coordinated Science Laboratory, University of Illinois Urbana-Champaign

08 *Hybrid dynamical systems - modeling, robustness, and hybrid feedback*, Systems and Control Seminar, Institute for Systems Theory and Automatic Control, University of Stuttgart

PUBLICATIONS

Books:

1. R. Goebel, A. Teel, and R. Sanfelice, *Hybrid dynamical systems. Modeling, stability, and robustness.*, Princeton University Press, 2012.

Refereed Journal Publications:

34. R. Goebel, *Lyapunov functions and duality for convex processes*, SIAM Journal on Control and Optimization, accepted June 2013

33. E.N.Barron, R. Goebel, and R.R. Jensen, *Functions which are quasiconvex under linear perturbations*, SIAM Journal on Optimization, Volume 22, Number 3, 1089–1108, 2012.

32. E.N.Barron, R. Goebel, and R.R. Jensen, *The quasiconvex envelope through first-order partial differential equations which characterize quasiconvexity of nonsmooth functions*, Discrete and Continuous Dynamical Systems, Series B, Volume 17, Issue 6, 1693–1706, 2012.

31. E.N.Barron, R. Goebel, and R.R. Jensen, *Quasiconvex Functions and Nonlinear PDEs*, Transactions of the AMS, accepted November 2011.

30. R. Goebel, W. Hare, X. Wang, *The optimal value and optimal solutions of the proximal average of convex functions*, Nonlinear Analysis: Theory, Methods & Applications, Volume 75, Issue 3, 1290–1304, 2012.

29. R. Goebel, *Set-valued Lyapunov functions for difference inclusions*, Automatica, Volume 47, Issue 1, 127–132, 2011.

28. R. Goebel, *The proximal average for saddle functions and its symmetry properties with respect to partial and saddle conjugacy*, Journal of Nonlinear and Convex Analysis, Volume 11, Number 1, 1–11, 2010.

27. E.N. Barron, R. Goebel, and R.R. Jensen, *Best response dynamics for continuous games*, Proceedings of the AMS, Volume 138, Issue 3, 1069–1083, 2010.

26. R. Goebel and A. Teel, *Pre-asymptotic stability and homogeneous approximation of hybrid dynamical systems*, SIAM Review, Volume 52, Issue 1, 87–109, 2010.

25. R. Goebel, C. Prieur, and A. Teel, *Smooth patchy control Lyapunov functions*, Automatica, Volume 45, 675–683, 2009.

24. R. Goebel and A. Teel, *Direct design of robustly asymptotically stabilizing hybrid feedback*, ESAIM: Control, Optimisation and Calculus of Variations, Volume 15, Number 1, 205-213, 2009.

23. C. Cai, R. Goebel, and A. Teel, *Relaxation theorems for hybrid inclusions*, Set-Valued Analysis, Volume 16, Issue 5, 733–757, 2008.

22. R. Goebel, R. Sanfelice, and A. Teel, *Invariance principles for switching systems via hybrid systems techniques*, Systems & Control Letters, Volume 57, Number 12, 980–986, 2008.

21. R. Sanfelice, R. Goebel, and A. Teel, *Generalized solutions to hybrid dynamical systems*, ESAIM: Control, Optimisation and Calculus of Variations, Volume 14, Number 4, 699–724, 2008.

20. H. Bauschke, R. Goebel, Y. Lucet, and X. Wang, *The proximal average: basic theory*, SIAM Journal on Optimization, Volume 19, Number 2, 766–785, 2008.

19. R. Goebel and R.T. Rockafellar, *Local strong convexity and local Lipschitz continuity of the gradient of convex functions*, Journal of Convex Analysis, Volume 15, Number 2, 263–270, 2008.

18. R. Goebel, *Self-dual smoothing of convex and saddle functions*, Journal of Convex Analysis, Volume 15, Number 1, 179–190, 2008.

17. C. Cai, A. Teel, and R. Goebel, *Smooth Lyapunov functions for hybrid systems. Part II: (Pre-)asymptotically stable compact sets*, IEEE Transactions on Automatic Control, Volume 53, Number 3, 734–748, 2008.

16. R. Sanfelice, R.Goebel, and A. Teel *Invariance principles for hybrid systems with connections to detectability and asymptotic stability*, IEEE Transactions on Automatic Control, Volume 52, Issue 12, 2282–2297, 2007.

15. C. Prieur, R. Goebel, and A. Teel, *Hybrid feedback control and robust stabilization of nonlinear systems*, IEEE Transactions on Automatic Control, Volume 52, Issue 11, 2103–2117, 2007.

14. C. Cai, A. Teel, and R. Goebel, *Smooth Lyapunov functions for hybrid systems. Part I: Existence is equivalent to robustness*, IEEE Transactions on Automatic Control, Volume 52, Issue 7, 1264–1277, 2007.

13. R. Goebel and M. Subbotin, *Continuous time constrained Linear Quadratic Regulator – convex duality approach*, IEEE Transactions on Automatic Control, Volume 52, Issue 5, 886–892, 2007.

12. R. Goebel, A. Teel, T. Hu, and Z. Lin, *Conjugate convex Lyapunov functions for dual linear differential inclusions*, IEEE Transactions on Automatic Control, Volume 51, Issue 4, 661–666, 2006.

11. R. Goebel and A. Teel, *Solutions to hybrid inclusions via set and graphical convergence with stability theory applications*, Automatica, Volume 42, Issue 4, 573–587, 2006.

10. T. Hu, A. Teel, R. Goebel, and Z. Lin, *Conjugate Lyapunov functions for saturated linear systems*, Automatica, Volume 41, Issue 11, 1949–1956, 2005.

9. R. Goebel, *Stabilizing a linear system with saturation through optimal control*, IEEE Transactions on Automatic Control, Volume 50, Issue 5, 650–655, 2005.

8. R. Goebel, *Duality and uniqueness of convex solutions to stationary Hamilton-Jacobi equations*, Transactions of the AMS, Volume 357, 2187–2203, 2005.

7. R. Goebel, *Convex optimal control problems with smooth Hamiltonians*, SIAM Journal of Control and Optimization, Volume 43, Number 5, 1787–1811, 2005.

6. R. Goebel, *Regularity of the optimal feedback and the value function in convex problems of optimal control*, Set-Valued Analysis, Volume 12, Issue 1-2, 127–145, 2004.

5. J. Borwein and R. Goebel, *Notions of relative interior in Banach spaces*, Journal of Mathematical Sciences, Volume 115, Issue 4, 2542–2553, 2003.

4. R. Goebel, *Planar generalized Hamiltonian systems with large saddle sets*, Journal of Nonlinear and Convex Analysis, Volume 3, Number 3, 365–380, 2002.

3. R. Goebel and R.T. Rockafellar, *Generalized conjugacy in Hamilton-Jacobi theory for fully convex Lagrangians*, Journal of Convex Analysis, Volume 9, Number 1, 463–473, 2002.

2. R. Goebel, *Convexity in zero-sum differential games*, SIAM Journal on Control and Optimization, Volume 40, Number 5, 1491–1504, 2002.

1. R. Goebel, *Sufficient condition for stability of an L^2-angle*, Bulletin of the Polish Academy of Science, Vol 45, No 3, 227–232, 1997.

Selected Refereed Conference Proceedings Contributions:

11. A.R. Teel, R. Goebel, B. Morris, A. Ames, J.W. Grizzle *A stabilization result with application to bipedal locomotion*, Proceedings of the 52nd Conference on Decision and Control, 2013.

10. R. Goebel *The Value Function for the Linear-Quadratic Regulator with Conical Control Constraints*, Proceedings of the 49th Conference on Decision and Control, 2010.

9. R. Goebel and A. Teel, *Zeno behavior in homogeneous hybrid systems*, Proceedings of the 47th Conference on Decision and Control, 2008.

8. R. Goebel and A. Teel, *Lyapunov characterization of Zeno behavior in hybrid systems*, Proceedings of the 47th Conference on Decision and Control, 2008.

7. R.T. Rockafellar and R. Goebel, *Linear-convex control and duality*, to appear in the Proceedings of the Geometric Control and Nonsmooth Analysis Conference, Rome 2006, Series on Advances in Mathematics for Applied Sciences.

6. R. Sanfelice, A. Teel, R. Goebel, and C. Prieur, *On the robustness to measurement noise and unmodeled dynamics of stability in hybrid systems*, Proceedings of the 2006 American Control Conference, 2006.

5. R. Sanfelice, R. Goebel, and A. Teel, *A feedback control motivation for generalized solutions to hybrid systems*, Hybrid Systems: Computation and Control: 9th International Workshop, HSCC 2006, Editors: J. Hespanha and A. Tiwari, Springer.

4. R. Goebel, A. Teel, T. Hu, and Z. Lin, *Dissipativity for dual linear differential inclusions through conjugate storage functions*, Proceedings of the 43nd IEEE Conference on Decision and Control, 2004.

3. R. Goebel, J. Hespanha, A. Teel, C. Cai, and R. Sanfelice, *Hybrid systems: generalized solutions and robust stability*, 6th IFAC Symp. on Nonlinear Contr. Systems, 2004.

2. D. Dačić, R. Goebel, and P. Kokotović, *A factorization approach to C^1 stabilization of nonlinear triangular systems*, Proceedings of the 42nd IEEE Conference on Decision and Control, Maui, 2003.

1. R. Goebel, *Stationary Hamilton-Jacobi equations for convex control problems — uniqueness and duality of solutions*, Optimal Control, Stabilization, and Nonsmooth Analysis; de Queiroz, M., M. Malisoff, and P. Wolenski, Editors; Lecture Notes in Control and Information Sciences, Springer-Verlag, 2004.

Other Contributions:

8. J. Borwein and R. Goebel, *On the nondifferentiability of cone-monotone functions in Banach spaces*, Optimization: Structure and Applications, E. Hunt and C. Pearce editors, Optimization and Its Applications, Volume 32, 3–14, Springer, 2009.

7. R. Goebel, R. Sanfelice, and A.R. Teel, *Hybrid dynamical systems. Robust stability and control for systems that combine continuous-time and discrete-time dynamics*, IEEE Control Systems Magazine, Volume 29, Issue 2, 28–93, 2009.

6. A.R. Teel, R. Sanfelice, and R. Goebel *Hybrid control systems*, Encyclopedia of Complexity and Systems Science, R.A. Meyers, Editor, Springer, 2009.

5. C. Cai, R. Goebel, R. Sanfelice, and A.R. Teel, *Hybrid systems: limit sets and zero dynamics with a view toward output regulation*, Analysis and Design of Nonlinear Control Systems. In Honor of Alberto Isidori, 237–257, Springer-Verlag, 2007.

4. R. Goebel, T. Hu, and A.R. Teel, *Dual matrix inequalities in stability and performance analysis of linear differential/difference inclusions*, Current trends in nonlinear systems and control, 103–122, Systems Control Found. Appl., Birkhuser Boston, Boston, MA, 2006.

3. R. Goebel, *Convexity, Convergence and Feedback in Optimal Control*, Doctoral Dissertation, Department of Mathematics, University of Washington, 2000.

2. R. Goebel, *Convexity and Hamiltonian equations in differential games*, Interim Report, International Institute for Applied Systems Analysis, August 1998.

1. R. Goebel, *On the Stability of an L^2-angle*, Masters Thesis (in Polish), Department of Mathematics, University of Maria Curie-Sklodowska, Lublin, Poland, 1994.

Submitted Contributions:

1. R. Goebel, *Continuum of Equilibria and Robustness of Stability Through Necessary and Sufficient Lyapunov-like Conditions*, submitted June 2013