

# Curriculum Vitae of Diego Regruto

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# 1 Personal data

**1.1 Home Address:** Chiaverano (TO), CAP 10010, via Tomalino 25, Italy.

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**1.2 Citizenship:** Italian

**1.3 Date and place of birth:** 20 January 1976 - Ivrea (TO), Italy.

**1.4 Marital Status:** married, two daughters.

**1.5 Language:** Italian (mother tongue), English (fluent)

# 2 Affiliation

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# 3 Current position

**3.1** January 1, 2008 - present: Tenured Assistant Professor of Automatic Control at Politecnico di Torino, Dipartimento di Automatica e Informatica.

# 4 Previous positions

**4.1** January 1, 2005 - December 31, 2007: Assistant Professor of Automatic Control at Politecnico di Torino, Dipartimento di Automatica e Informatica.

**4.2** February 1, 2004 - December 31, 2005: Research assistant at Politecnico di Torino, Dipartimento di Automatica e Informatica (research project: "Identification and control of complex systems").

**4.3** January 1, 2001 - December 31, 2003: Ph.D student in System engineering, Politecnico di Torino, Dipartimento di Automatica e Informatica.

## 5 Education

**5.1 Ph.D in System engineering**, Politecnico di Torino, Dipartimento di Automatica e Informatica, May 6, 2004.

Thesis title: *Identification of nonlinear block structured systems from measurements affected by unknown but bounded errors.*

**5.2 Master of science degree in electrical engineering**, Politecnico di Torino, December 12, 2000.

Thesis title: *Lateral vehicle dynamics control for automatic lane keeping.*

## 6 Research activity

The research activity has been mainly carried out in the areas of system identification, robust control and convex relaxations methods with application to automotive and biomedical problems. A brief summary of the problems addressed in the research activity is reported here.

**Parameter estimation in the set-membership context** Parameter estimation in the set-membership context deals with the identification of a set of all possible parameters of a system consistent with the measurements, the assumed model structure and the hypothesis on the error. Differently from the stochastic identification framework, in the set-membership context the statistical description of the noise on the measurements is not available and the only information on such an error is that its amplitude or energy is bounded. The problem of identifying linear systems when both input and output data are corrupted by bounded noise (bounded errors-in-variables problem) is considered in [J10, J13], while Hammerstein and Wiener systems identification is addressed in [J16, J14, J3, J1]. Approaches for bounding the parameters of Hammerstein-like and Wiener-like structures with backlash are discussed in [J4, J14]. A procedure for set-membership identification of block-structured nonlinear feedback systems is proposed in [J15]. In all the works mentioned above, the identification problem is formulated in terms of nonconvex polynomial optimization and suitable convex-relaxation based on linear programming (LP) and/or linear matrix inequalities (LMIs) are proposed to efficiently compute guaranteed bounds on the parameters of the considered system.

**Identification of linear-parameter-varying models** Linear-parameter varying (LPV) models belong to the more general class of linear time-varying systems and, roughly speaking, they can be defined as linear systems where, either the matrixes of the state equations or the coefficients of the input-output relation, depend on one or more time varying parameters, whose real-time samples are assumed to be available. In [B2, C27, C20], different approaches are presented to identify LPV models when both the output data and the scheduling parameters are corrupted by bounded-noise. The work [C31] addresses the problem of computing the LPV model minimizing the approximation error introduced by applying LTI-realization theory to derive a state-space description of an LPV model originally described in an input-output form. Set-membership LPV identification theory is exploited in [J11] to derive an LPV model describing vehicle lateral dynamics, and in [C35] to describe glucose-insulin dynamics in a patient affected by diabetes.

**Enforcement of stability constraints in system identification** Although many times the system to be identified is surely known to be stable, most of the identification techniques do not exploit such a prior information in the definition of the assumed model structure. As a result, the identification procedure may give rise to inaccurate models and even instability may arise, especially in the presence of shortage of data, modeling error and high measurement noise. The problem of enforcing stability constraints and/or quadratic stability constraints in the identification of linear-time-invariant systems and linear-parameter varying systems is addressed in [J12] and [C37], respectively.

**Design of robust controller from experimental data** This research activity concerns the design of robust controllers starting from a set of input-output data collected performing some experiments on the plant to be controlled. In particular, the considered approach is based on a two-stage procedure: first, set-membership identification techniques are used to derive an uncertainty model set for the plant; then, an originally proposed robust control method is used to design a two-degrees-of-freedom controller. The key feature of this solution is the ability to deal with both casual and noncasual feedforward controllers. The latter case is of interest in some relevant applications (e.g. control of machine tools) where a preview of the reference tracking signal is often available. The obtained results are reported in the following papers: [J5], [J2], [C4] [C3], [C1].

**Automotive applications - modeling, identification and control of the vehicle lateral dynamics** In this research activity, conducted in collaboration with the FIAT research center (CRF), new ad-hoc approaches for modeling, identification and control of the lateral vehicle dynamics have been derived exploiting tools and algorithms obtained as results of the methodological research activities summarized above. In particular, the main obtained results are the following:

- A new algorithm for automatic lane-keeping via steering feedback control has been derived and experimentally tested on the Italian highways using a properly equipped FIAT prototype car.
- An original ad-hoc robust two-degree of freedom control scheme has been proposed, and experimentally tested on a real car, to smoothly combine the automatic lane keeping system with the driver's steering action.
- An accurate control-oriented LPV model of the vehicle lateral dynamics has been derived from a set of real experimental data, exploiting original results on set-membership identification of LPV systems.
- A new iterative approach, based on a proper combination of  $H_\infty$  control and set-membership identification, has been proposed for designing robust controllers for yaw rate stabilization in emergency maneuvers.
- An original identification-based approach for designing a virtual sensor able to perform real-time estimation of the vehicle sideslip angle has been proposed and tested using sets of experimental data.

The most important obtained results are reported in the following papers: [J11, J8, J7, C13, C8].

## 7 Teaching activities

- Teacher of the *Automatic Control* class for Biomedical engineering, Politecnico di Torino, Academic Years 2010-2011, 2011-2012, 2012-2013.

- Teacher (together with Prof. Vito Cerone) of the *Modern and robust control* class for Mechatronics engineering, Politecnico di Torino, Academic Years 2011-2012, 2012-2013.
- Teacher (together with Prof. Vito Cerone) of the *Modern Control Synthesis* class for the 2nd level specializing Master in Automatica and control technologies, Politecnico di Torino, Academic Years 2010-2011, 2011-2012.
- Teacher of the *Automatic Control* class for Automotive engineering, Politecnico di Torino, Academic Year 2009-2010.
- Teacher of the *Principles of Automatic Control* class for Automotive engineering, Politecnico di Torino, Academic Years 2005-2006, 2006-2007, 2007-2008, 2008-2009.

## 8 Participation in research projects

Dr. Diego Regruto was involved in the research teams of about 20 research projects funded by the Italian research ministry, the Piedmont region and some private companies.

## 9 Editorial activities and contribution to international scientific society

- Active member of the IEEE CSS Technical Committee on System Identification and Adaptive Control since December 2008.
- Corresponding guest editor of the IEEE Transactions on Automatic Control Special Issue on "Relaxation Methods in Identification and Estimation Problems" (<http://www.nd.edu/ieeetac/special.html>).
- Co-organizer of the invited session "Convex relaxation techniques in system identification" (50th IEEE Conference on Decision and Control) and of the invited session "Convex Relaxation in Identification and Control" (51st IEEE Conference on Decision and Control).
- Reviewer for the most renowned international journals in the automatic control/system identification fields including the IEEE Transactions on Automatic Control, Automatica, the IEEE Transactions on Control Systems technology, the International Journal of Adaptive Control and Signal Processing, the International Journal of Robust Control, the International Journal of Control, Systems and Control Letters.

# 10 Publications

## International Journals

- [J16] V. Cerone, D. Piga, D. Regruto, "Computational load reduction in bounded error identification of Hammerstein systems," *IEEE Transactions on Automatic Control*, In press.
- [J15] V. Cerone, D. Piga, D. Regruto, "Bounding the parameters of block-structured nonlinear feedback systems," *International journal of robust and nonlinear control*, In press, available on-line (DOI: 10.1002/rnc.1813).
- [J14] V. Cerone, D. Piga, D. Regruto, "Bounded error identification of Hammerstein systems through sparse polynomial optimization," *Automatica*, vol. 48, No. 10, pp. 2693-2698, 2012.
- [J13] V. Cerone, D. Piga, D. Regruto, "Set-Membership Error-in-Variables Identification Through Convex Relaxation Techniques," *IEEE Transactions on Automatic Control*, vol. 57, No. 2, pp. 517-522, 2012.
- [J12] V. Cerone, D. Piga, D. Regruto, "Enforcing stability constraints in set-membership identification of linear dynamic systems," *Automatica*, vol. 47, No. 11, pp. 2488-2494, 2011.
- [J11] V. Cerone, D. Piga, D. Regruto, "Set-membership LPV model identification of vehicle lateral dynamics," *Automatica*, vol. 47, No. 8, pp. 1794-1799, 2011.
- [J10] V. Cerone, D. Piga, D. Regruto, "Improved parameters bounds for set-membership EIV problems," *International Journal of adaptive control and signal processing*, vol. 25, No. 3, pp. 208-227, 2011.
- [J9] V. Cerone, D. Andreo, M. Larsson, D. Regruto, "Stabilization of a riderless bicycle: a Linear-Parameter-Varying approach," *IEEE Control systems magazine*, vol. 30, No. 5, pp. 23-32, 2010.
- [J8] V. Cerone, M. Milanese, D. Regruto, "Yaw stability control design through a mixed sensitivity approach," *IEEE Transactions on Control Systems Technology*, vol. 17, No. 5, pp. 1096-1104, 2009.
- [J7] V. Cerone, M. Milanese, D. Regruto, "Combined automatic lane-keeping and driver's steering through a two DOF control strategy," *IEEE Transactions on Control Systems Technology*, vol.17, No. 1, pp.135-142, 2009.
- [J6] V. Cerone, M. Canale, D. Regruto, "Loop-shaping design with constant magnitude loci in control education," *International Journal of Engineering Education*, vol. 24, No. 1, pp. 127-136, 2008.
- [J5] V. Cerone, M. Milanese, D. Regruto, "Robust Feedforward Design for a Two Degrees of Freedom Controller," *System and Control Letters*, vol. 56, pp. 736-741, 2007.
- [J4] V. Cerone, D. Regruto, "Bounding the parameters of linear systems with input backlash," *IEEE Transactions on Automatic Control*, vol. 52, No. 3, pp. 531-536, 2007.
- [J3] V. Cerone, D. Regruto, "Parameter bounds evaluation of Wiener models with noninvertible polynomial nonlinearities," *Automatica*, vol. 42, No. 10, pp. 1775-1781, 2006.

- [J2] S. Malan, M. Milanese, D. Regruto, M. Taragna, "Robust control from data via uncertainty model sets identification", *International Journal of Robust and Nonlinear Control*, vol. 14, No. 11, pp. 945-957, 2004.
- [J1] V. Cerone, D. Regruto, "Parameter bounds for discrete-time Hammerstein models with bounded output errors," *IEEE Transactions on Automatic Control*, vol. 48, No. 10, pp. 1855-1860, 2003.

## Book chapters

- [B2] V. Cerone, D. Piga, D. Regruto, "SM identification of IO LPV models with uncertain time-varying parameters," in **Linear parameter-varying system identification, New Developments and Trends** (edited by Lopes dos Santos P., Azevedo Perdicolis T., Novara C., Ramos J., Rivera D.,) pp. 289-306, World Scientific (Advanced Series in Electrical and Computer Engineering), pp. 41-64, 2011.
- [B1] V. Cerone, D. Piga, D. Regruto, "Bounded error identification of Hammerstein systems with backlash," in **Block-oriented nonlinear system identification** (edited by F. Giri, E. W. Bai,) Springer (Lecture notes in Control and Information sciences), 2010.

## International conferences

- [C37] V. Cerone, D. Piga, D. Regruto, R. Toth, "Input-Output LPV Model Identification with Guaranteed Quadratic Stability" , IFAC SYSID 2012.
- [C36] V. Cerone, D. Piga, D. Regruto, "FIR Approximation of Linear Systems from Quantized Records" , IFAC SYSID 2012.
- [C35] V. Cerone, D. Piga, D. Regruto, B. Sintayehu, "LPV Identification of the Glucose-Insulin Dynamics in Type I Diabetes" , IFAC SYSID 2012.
- [C34] V. Cerone, D. Piga, D. Regruto, "Bounded-Error Identification of Linear Systems with Input and Output Backlash" , IFAC SYSID 2012.
- [C33] V. Cerone, D. Piga, D. Regruto, "Robust Pole Placement for Plants with Semialgebraic Parametric Uncertainty" , IEEE ACC 2012.
- [C32] M. Canale, V. Cerone, V. Razza, D. Regruto, "Rapid Prototyping of Predictive Controllers through an Industrial Platform" , IEEE ACC 2012.
- [C31] V. Cerone, D. Piga, D. Regruto, R. Toth, "Minimal LPV State-Space Realization Driven Set-Membership Identification" , IEEE ACC 2012.
- [C30] V. Cerone, D. Piga, D. Regruto, "Set-Membership identification of Hammerstein-Wiener systems" , IEEE CDC 2011.
- [C29] M. Canale, V. Cerone, D. Piga, D. Regruto, "Fast implementation of Model Predictive Control with guaranteed performance" , IEEE CDC 2011.
- [C28] V. Cerone, D. Piga, D. Regruto, "Computational Burden Reduction in Set-Membership Hammerstein System Identification" , IFAC World Congress 2011.

- [C27] V. Cerone, D. Piga, D. Regruto, "Convex Relaxation Techniques for Set-Membership Identification of LPV Systems", American Control conference 2011.
- [C26] V. Cerone, D. Piga, D. Regruto, "Hammerstein Systems Parameters Bounding through Sparse Polynomial Optimization", American Control conference 2011.
- [C25] V. Cerone, D. Piga, D. Regruto, "Bounding the parameters of linear systems with stability constraints", American Control conference 2010, Baltimore, Maryland (USA), June, 2010.
- [C24] V. Cerone, D. Piga, D. Regruto, "Set-membership EIV identification through LMI relaxation techniques", American Control conference 2010, Baltimore, Maryland (USA), June, 2010.
- [C23] D. Andreo, V. Cerone, D. Dzung, D. Regruto, "Experimental results on LPV stabilization of a riderless bicycle" 2009 American Control Conference, St. Louis, Missouri (USA), June, 2009
- [C22] V. Cerone, D. Piga, D. Regruto, "Set-membership Identification of Block-Structured Non-linear Feedback Systems" 48th IEEE Conference on Decision and Control, Shangai (China), December, 2009
- [C21] V. Cerone, D. Piga, D. Regruto, "Parameter bounds evaluation for linear system with output backlash" 15th IFAC Symposium on System Identification SYSID, Saint-Malo (France), July, 2009
- [C20] V. Cerone, D. Regruto, "Set-membership Identification of LPV models with uncertain measurements of the time-varying parameter", 47th IEEE Conference on Decision and Control, Cancun, Mexico, December, 2008.
- [C19] V. Cerone, M. Milanese, D. Regruto, "Hardware-in-the-loop (HIL) results on yaw stability control," 2007 IEEE Multi-conference on Systems and Control, Singapore, October 1-3, 2007.
- [C18] V. Cerone, M. Milanese, D. Regruto, "Combined automatic lane-keeping and driver's maneuvers through a closed loop control strategy," Fifth IFAC Symposium on Advances in Automotive Control, Monterey Coast, California, USA, August 20-22, 2007.
- [C17] E.W. Bai, V. Cerone, D. Regruto, "Separable Inputs for the Identification of Block-Oriented Nonlinear Systems", 2007 American Control Conference, New York, NY, USA, July 11-13, 2007.
- [C16] V. Cerone, M. Milanese, D. Regruto, "Experimental Results on Combined Automatic Lane Keeping and Driver's Steering", 2007 American Control Conference, New York, NY, USA, July 11-13, 2007.
- [C15] V. Cerone, M. Milanese, D. Regruto, "Simulation results on combined automatic lane keeping and driver's maneuvers," 2007 European Control Conference, Kos, Greece, July 2-5, 2007.
- [C14] V. Cerone, M. Milanese, D. Regruto, "Yaw stability control design through a mixed sensitivity approach," 2007 IEEE Intelligent Vehicles Symposium, Istanbul, Turkey, June 13-15, 2007.
- [C13] M. Milanese, D. Regruto, A. Fortina, "Direct Virtual Sensor (DVS) design in vehicle sideslip angle estimation", 2007 American Control Conference, New York, NY, USA, July 11-13, 2007.
- [C12] V. Cerone, M. Canale, D. Regruto, "An extended Nichols chart with constant magnitude loci of sensitivity and complementary sensitivity functions for loop-shaping design," 7th IFAC Symposium on Advances in Control Education, Madrid, Spain, June 21-23, 2006.



- [C11] V. Cerone, D. Regruto, "Set-Membership identification of linear systems with input backlash," American Control Conference 2006, Minneapolis, Minnesota, USA, June 12-14, 2006.
- [C10] V. Cerone, D. Regruto, "Set-Membership identification of Wiener models with non-invertible nonlinearity," 16th IFAC World Congress, Prague, July 4-8, 2005.
- [C9] V. Cerone, D. Regruto, "Bounding the parameters of linear systems with input backlash," American Control Conference 2005, Portland, OR, USA, June 8-10, 2005.
- [C8] V. Cerone, D. Regruto, "Robust performance controller design for vehicle lane keeping," European Control Conference 2003, Cambridge, UK, September, 2003.
- [C7] V. Cerone, M. Milanese, D. Regruto, "Parameter set evaluation of Wiener models from data with bounded output errors," 13th IFAC Symposium on System Identification, Rotterdam, August, 2003, pp. 875-880.
- [C6] V. Cerone, D. Regruto, "A two-stage parameter bounding procedure for Hammerstein models with bounded output errors," American Control Conference 2003, Denver, Colorado, USA, June, 2003, pp. 2943-2948.
- [C5] V. Cerone, D. Regruto, "Vehicle lateral controller design exploiting properties of SITO systems," American Control Conference 2003, Denver, Colorado, USA, June, 2003, pp. 4365-4370.
- [C4] S. Malan, M. Milanese, D. Regruto, M. Taragna, "Guaranteed performances design via model sets identification", 4th IFAC Symposium on Robust Control Design, Milano, Italia, 2003.
- [C3] V. Cerone, M. Milanese, D. Regruto, "Robust feedforward design from data via approximate inverse SM identification," 41st IEEE Conference on Decision and Control, Las Vegas, Nevada, USA, December, 2002, pp. 4664-4669.
- [C2] V. Cerone, A. Chinu, D. Regruto, "Experimental results in vision based lane keeping for highway vehicles," American Control Conference 2002, Anchorage, Alaska, USA, May, 2002, pp. 869-874.
- [C1] S. Malan, M. Milanese, D. Regruto, M. Taragna, "Robust control from data via uncertainty model sets identification", 40th IEEE Conference on Decision and Control, Orlando, Florida, 2001, pp. 2686-2691.