SOME RECENT RESEARCH INTERESTS

1 Modeling and Realization of Stochastic Systems

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This has been one of my main research interests for about forty years. *Stochastic Realization Theory* has emerged from this work as a fundamental contribution to stochastic model building and Stochastic Systems Theory, which has developed over the years and is now been collected in a monograph co-authored with Anders Lindquist entitled *Linear Stochastic Systems: a Geometric Approach.* Stochastic Realization Theory is centered around the original idea of *Markovian Splitting Subspace* and *Markovian representation* of a random signal, which is a natural probabilistic analog of the notion of *state* and state-space model in deterministic dynamical systems and is rooted on the Bayesian notion of sufficient statistics. This new theoretical framework has provided a mathematical theory of model building which has provided the conceptual basis for later work on subspace identification and has led for the first time to the understanding of structural properties of stochastic systems like minimality, which are important in applications to filtering and recursive estimation algorithms of minimal dimension. For example a new minimal–complexity solution of a class of noncausal estimation problems has been found and a new role of the family of *all* solutions of the Algebraic Riccati Equation in the computation of the optimal noncausal estimator has been discovered.

The idea of stochastic state (splitting) has been applied to various types of signals, e.g. to finite-state processes. Stochastic realization in this context has the purpose of finding algorithms for modelling finite-state signals as functions of a finite state Markov Chain (what is now called a "hidden Markov Chain"). This problem is being now recognized as a key problem in signal processing with many potential applications to source coding, speech recognition etc.. Work in this area has started in the 70's and has continued until recently in collaboration with Jan van Schuppen.

Below I list the papers where the concept of splitting was shown to be the natural counterpart of the idea of "state" in the stochastic setting and the basic ideas of stochastic realization theory were introduced.

1. G. Picci: Stochastic realization of Gaussian processes *Proceedings of the IEEE* Vol.**64**, No. 1, pp 112-122, 1976.

2. G. Picci: Some connections between the theory of sufficient statistics and the identifiability problem *SIAM Journal on Applied Mathematics* Vol.**33**, No. 3, pp 383-398, 1977.

3. G. Picci: On the internal structure of finite-state stochastic processes in *Recent developements in Variable Structure Systems* R. Mohler and A. Ruberti eds.(Proceedings of the third Italy-USA symposium on Variable-Structure Systems, Taormina, Italy, September 1977),*Springer Lecture Notes in Economics andMathematical Systems*, Vol **162**, pp. 288-304, 1978.

4. A. Lindquist, G. Picci and G. Ruckebusch: On minimal splitting subspaces and Markovian representation *Mathematical Systems Theory* Vol. **12**, pp. 271-279, 1979.

5. A. Lindquist and G. Picci: On the stochastic realization problem *SIAM Journal on Control and Optimization* Vol. **17**, No. 3, pp. 365-389, 1979.

6. L. Finesso and G. Picci: A characterization of minimal square spectral factors *IEEE Transactions on Automatic Control* Vol.**AC-27**, No. 1, pp. 122-127, 1982.

7. A. Lindquist and G. Picci: On a condition for minimality of Markovian splitting subspaces *Systems And Control Letters* Vol. **1**, No. 4, pp. 264-269, 1982.

8. A. Lindquist, S. K. Mitter and G. Picci: Toward a theory of nonlinear stochastic realization in *Feedback and Control of Linear and Nonlinear Systems* D. Hinrichsen and A. Isidori eds. *Springer Lecture Notes on Control and Information Sciences*, Vol **39**, pp. 175-189, 1982.

9. A. Lindquist and G. Picci: Forward and backward semimartingale models for stationary increments processes *Stochastics*, Vol. **15**, No. 5 ,pp. 1-50, 1985.

10. A. Lindquist and G. Picci: Realization theory for multivariate stationary Gaussian processes *SIAM Journal on Control and Optimization* Vol.**23**, No. 6 pp. 809-857, 1985 (invited paper).

11. A. Lindquist and G. Picci: A geometric approach to modeling and estimation of linear stochastic systems *Journal of Math. Systems, Estimation and Control* vol.**1**, pp. 241–333, 1991.

12. G. Picci: Stochastic modeling and stochastic realization theory in *Mathematical System Theory: the influence of R.E. Kalman*, R.E. Kalman Festschrift voume, A. Antoulas ed., Springer Verlag, pp. 213–229, 1991.

13. A. Lindquist, S. K. Mitter and G. Picci: Toward a theory of nonlinear stochastic realization in *Feedback and Control of Linear and Nonlinear Systems* D. Hinrichsen and A. Isidori eds. *Springer Lecture Notes on Control and Information Sciences*, Vol **39**, pp. 175-189, 1982.

14. G. Picci and S. Pinzoni: Acausal Models and Balanced realizations of stationary processes *Linear Algebra and its Applications* (special issue on Systems Theory), vol. **205-206**, pp. 957-1003, 1994.

15. A. Lindquist, G. Michaletzky and G. Picci Zeros of Spectral Factors,the geometry of Splitting Subspaces and the Algebraic Riccati Inequality, *SIAM J. on Control and Optimization*,**33**, pp. 365-401, March 1995.

16. G. Picci, "Geometric methods in Stochastic Realization and System Identification", *CWI Quarterly* (invited paper), **9**, pp. 205-240, 1996.

17. A Ferrante and G. Picci, "Minimal Realization and Dynamic Properties of Optimal Smoothers" *IEEE Transactions on Automatic Control*, vol. **45**, 2000, pp. 2028-2046.

18. A. Ferrante, G. Picci, and S. Pinzoni "Silverman algorithm and the structure of discrete-time stochastic systems, *Linear Algebra and its Applications* special issue on systems and control, **351-352**, pp. 219-242 (2002).

19. A. Lindquist and G. Picci, *Linear Stochastic Systems: A Geometric Approach to Modeling, Estimation and Identification*, Springer series in Contemporary Mathematics. Springer Verlag, 2015. The book has been translated into Chinese in 2018.

20. A Ferrante and G. Picci, Representation and Factorization of Discrete-Time Rational All-Pass Functions, *IEEE Transactions on Automatic Control*, Nov. 2016, DOI: 10.1109/TAC.2016.2628163.

21. A. Lindquist and G. Picci, Modeling of Stationary Periodic Time Series by Bilateral and Unilateral ARMA Representations, in *Optimization and Applications in Control and Data Science*, Springer Series in Optimization 115, pp 281-314, August 2016.

22. A Ferrante and G. Picci, On the state space and dynamics selection in linear stochastic models: a spectral factorization approach, *IEEE Transactions on Automatic Control*, vol. 64, pp. 2509-2513, June 2019.

2 Identification and Subspace identification

Early work in the field of identification has been on identifiability and parametrization of multivariable models. Recent works has mostly been on *subspace identification.* There are basically two different approaches to the problem of fitting a model to observed data. The first, the *optimization approach*, is based on the principle of minimizing a suitable distance function between the data and the chosen model class. Well-known and widely accepted examples of distance functions are the likelihood function and the average squared prediction-error of the observed data. For multivariable models the optimization approach has several drawbacks. First there are rather subtle identifiability and parametrization issues which are traditionally solved by use of canonical forms. These however tend to lead to ill-conditioned estimation problems. Next, the likelihood (or prediction error) minimization can, except in trivial cases, only be done numerically by iterative algorithms in the parameter space, say in the space of minimal (A, B, C, D) matrix quadruples. For this reason there is no guarantee of reaching a true minimum and often a time-consuming random search in the parameter space is necessary to validate the estimates.

The subspace identification approach is not based on optimization. It may be described as a two steps procedure by which one first constructs a *state* for the observed process, and then does regression on a state space model. The successive noise model identification step requires the solution of a Riccati equation. This is a system-theoretic paradigm essentially rooted on stochastic realization theory. It is well-known that subspace methods do not require the a priori choice of identifiable parametrizations and can be implemented by fast and reliable numerical schemes. A statistical assessment of these methods has been an open problem for some time. Work in collaboration with A. Chiuso has lead to substantial progress on the statistical analysis of subspace methods.

1. G. Picci: Some connections between the theory of sufficient statistics and the identifiability problem *SIAM Journal on Applied Mathematics* Vol.**33**, No. 3, pp 383-398, 1977.

2. G. Picci: Some numerical aspects of multivariable system identification *Mathematical Programming Studies*, Vol. **18**, pp. 76-101, 1982.

3. A. Lindquist and G. Picci, "Geometric Methods for State-Space Identification", in *Identification, Adaptation, Learning*, *NATO-ASI: From Identifiation to Learning* Como, Italy Aug. 1994), S. Bittanti and G. Picci. eds, Springer Verlag, pp. 1-69, 1996.

4. G. Picci and T. Katayama, "Stochastic realization with exogenous inputs and subspace methods identification", *Signal Processing*, special issue on subspace methods, Part II: System Identification, **52**, n.2, pp. 145-160, 1996.

5. A. Lindquist and G. Picci, Canonical correlation analysis , approximate covariance extension and identification of stationary time-series, *Automatica*, vol **32**, pp. 709-733, 1996.

6. T. Katayama and G. Picci, " Realization of Stochastic Systems with Exogenous Inputs and Subspace Identification Methods", *Automatica*, vol. **35**, no. 10, pp. 1635-1652, 1999.

7. Chiuso, A. and Picci G. "Some Algorithmic aspects of Subspace Identification with Inputs", *Applied Mathematics and Computer Sciences*, **11**, 1, pp. 55-76 (2001).

8. A. Chiuso and G. Picci (2004), "Asymptotic Variance of Subspace Estimates". *Journal of Econometrics*, **118**(1-2), pp. 257–291.

9. A. Chiuso, G. Picci (2004), "On the Ill-conditioning of subspace identification with inputs". *Automatica*, **40**(4), pp. 575-589.

10. A. Chiuso, G. Picci (2004), "Numerical conditioning and asymptotic variance of subspace estimates". *Automatica*, **40**(4), pp. 677-683.

11. A. Chiuso and G. Picci (2004), , "Subspace identification by data orthogonalization and model decoupling", *Automatica*, **40**(4), pp. 1689-1703.

12. A. Chiuso and G. Picci (2004), "Asymptotic Variance of Subspace Methods by Data Orthogonalization and Model Decoupling: a Comparative Analysis", *Automatica*, **40**(4), pp. 1705–1717.

13. A. Chiuso and G. Picci (2005), "Consistency Analysis of some Closed-loop Subspace Identification Methods", *Automatica: special issue on System Identification*, **41** pp. 377-391.

14. T. Katayama, H. Kawauchi and G. Picci (2005), “Subspace Identification of Closed Loop Systems by Orthogonal Decomposition”, *Automatica* **41** pp. 863-872.

15. A. Chiuso, G. Picci (2005), “Prediction Error vs. Subspace Methods in Closed Loop Identification”. *Proc of the 16th IFAC World Congress*, Prague.

16. A. Chiuso and G. Picci (2006) “Estimating the Asymptotic Variance of Closed-Loop Subspace Estimators,” in *Proc. of SYSID 2006*, Newcastle, Australia, March 2006.

17. M. Favaro and. G. Picci (2012) Consistency of subspace methods for signals with almost-periodic components, *Automatica*, Volume 48, Issue 3, March 2012, Pages 514-520, doi: org 10.1016j.automatica.2011.08.059.

18. M. Favaro and. G. Picci (2012) A subspace algorithm for extracting periodic components from multivariable signals in colored noise, *Proc 16th IFAC Symposium on System Identification (SYSID)*, Bruxelles, pp. 1150 -1155.

19. G. Picci and Bin Zhu, An Empirical Bayesian Approach to Frequency Estimation, arXiv: 1910.09475v1 [eess.SP].

20. G. Picci and Bin Zhu, Bayesian Frequency Estimation on Narrow Bands, *Proceedings of the 2021 IFAC-SYSID , Padova, Italy.* IFAC-PapersOnLine, 54, 7, pp. 108–113,
also in arXiv: 2012.05004

21. G. Picci and Bin Zhu, Empirical Bayes Identification of Stationary Processes and Approximation of Toeplitz Spectra, *Automatica*, vol 142, 110362 (2022) . also in arXiv: 2009.05758.

3 Factor Analysis and Errors-in-Variables Modeling

It is well-known that ARMAX models treat the observed variables in an asymmetric manner, since a distinction is made from the outset of which varibles in the model are ”inputs” and which are ”outputs”. In particular input variables are assumed to be observed without error. As much argued by Kalman, these models may be inappropriate (”prejudiced”) descriptions

to impose to real data coming from economic time series or industrial processes involving feedback.
“Unprjudiced” models like Error–in Variables (EIV) or Factor–Analysis (FA) models, have been around for several years in the statistical literature but serious identifiability problems for these models have hampered their application. Solving the intrinsic "unidentifiability", or better the inherent non–uniqueness of these models has been an open problem for decades. The unidentifiability problem for a class of FA models (for the so–called "two–blocks" models), both static and dynamic, has been thoroughly studied in a paper appeared in the *Journal of Econometrics* in 1989. There it shown that the continuum of minimal FA models describing two given random signals can be parametrized explicitly by a certain projection matrix. The choice of a particular model (i.e. projection matrix) results in *exact* (i.e. with no modelling error) representation of a particular subset of the output variables while the complementary subset is instead represented with a maximal modelling error variance. A uniquely identifiable model can be selected by choosing how much representaton error variance one is willing to tolerate on each output vector. The identifiability of EIV models with white measurement errors (the so-called Frisch scheme) has been also addressed recently

1. G. Picci and S. Pinzoni: Dynamic Factor-Analysis models for stationary processes *IMA Journal on Mathematics of Control and Information* Vol.**3**, No. 2 , pp. 185-210, 1986.

2. G. Picci: Parametrization of Factor Analysis models *Journal of Econometrics* Vol. **41**, No. 1 pp. 17-38, 1989.

3. G. Picci, F Gei and S. Pinzoni: Errors–in–Variables models with white measurement errors, *Proc. 2nd European Control Conference (ECC)*, p. 2154-2158, Groningen the Netherlands, 1993.

4. G. Bottegal, G. Picci and S.Pinzoni (2011), On the identifiability of errors-in-variables models with white measurement errors, *Automatica* **47** pp. 545–551.

5. G. Bottegal and G. Picci (2011), A note on Generalized Factor Analysis models, *Proc. 50th Decision and Control Conference (CDC)*, pp. 1485-1490, Orlando FLA, USA.

6. G. Picci and G. Bottegal, Generalized Factor Analysis Models, in *Control Theory: Mathematical Perspectives on Complex Networked Sys-*

tems, Frank Allgöwer, Vincent Blondel, Uwe Helmke Eds, Mathematisches Forschungsinstitute Oberwolfach, Oberwolfach, Germany, pp. 705-706, 2012, doi = 10.4171/OWR/2012/12.

7. G. Bottegal and G. Picci (2013), Modeling random flocks through Generalized Factor Analysis *Proc. of European Control Conference ECC13* Zürich, pp. 2421–2426.

8. G. Bottegal and G. Picci, Analysis and identification of complex stochastic systems admitting a flocking structure, *Proc of the 19th IFAC World Congress*, Capetown, South Africa, Aug. 2014, pp. 2323-2328.

9. G. Bottegal and G. Picci, Modeling complex systems by Generalized Factor Analysis, *IEEE Transactions on Automatic Control*, **60**: pp 759 - 774, February 2015.
   doi: 10.1109/TAC.2014.2357913.

10. G. Picci, L. Falcon, A. Ferrante and M. Zorzi, Hidden Factor estimation in Dynamic Generalized Factor Analysis Models, *Automatica*, 2022.

4 Stochastic model reduction by aggregation

The papers listed below document a tentative of understanding how well a stochastic reduced order model could represent a "complicated " deterministic system. This work elaborates theoretically on the observation that in many practical situations stochastic models work well as thy are effectively *reduced–order descriptions* of large deterministic systems in which "parasitcs" and variables coupling with the environment are represented as additive "noise" in the dynamical equations. A well–known problem in many areas of control, but especially in adaptive control, is how to cope with unmodelled dynamics. There seems to be some evidence that control schemes which use *stochastic* models and stochastic description of the environment are more robust to unmodelled dynamics.

1. G.Picci: Application of stochastic realization theory to a fundamental problem of statistical physics (invited keynote address at MTNS-85) in *Modelling, Identification and Robust Control* C. I. Byrnes, A. Lindquist eds. North Holland, pp. 211-258 1986.

2. G. Picci: Aggregation of linear systems in a completely deterministic framework in *Three Decades of Mathematical System Theory. A Collection of Surveys at the Occasion of the Fiftieth Birthday of Jan C. Willems*, H. Neijmeijer, J.M. Schumacher eds., *Springer Lecture Notes in Control and Information Sciences*, Vol.**135** pp. 358-381, 1989.

3. G.Picci Stochastic model reduction by aggregation in *Systems Models and Feedback: Theory and Applicatons*, A Isidori, T.J. Tarn eds., Proc. of a Workshop held in the occasion of the 65-th aniversary of A. Ruberti, Capri, italy, June 1992.

4. G. Picci and T.S.J. Taylor: Generation of Gaussian Processes and Linear Chaos. *Proc 31st IEEE Conf. on Decision and Control* Tucson Arizona, pp. 2125–2131, 1992.

5. G. Picci and T.S.J. Taylor: Stochastic aggregation of flexible mechanical structures *Recent advances in Mathematical Theory of Systems, Control,Networks and Signal Processing II*, H. Kimura, S. Kodama eds. (Proceedings of MTNS-91, Kobe 1991), pp. 203–207, Mita press, Tokyo, 1992.

6. G. Picci: Markovian representation of linear Hamiltonian systems, in *Probabilistic Methods in Mathematical Physics*, F. Guerra, M.I. Loffredo and C. Marchioro eds. World Scientific Singapore, pp. 358–373, 1992.

4.1 Stochastic Control and applications

Below are some representative papers addressing various issues related to LQG, H^∞ control and applications of identification to real systems.

1. G.B. Di Masi, L. Finesso and G. Picci: Design of an LQG controller for single-point moored large tankers *Automatica* Vol.**22**, No. 2, pp. 155-169, 1986.

2. G. Picci and S. Pinzoni: On feedback-dissipative systems *Journal of Math. Systems, Estimation and Control* vol.**2**, No. 1, pp. 1–30, 1992.

3. R. Muradore and G. Picci (2005), "Mixed H^2/H^∞ control: the discrete-time case", *Systems and Control Letters*, **54**, pp. 1-13.

5 Covariance Extension and applications

The general idea of this project is to study identification of stationary processes as a map transforming a *finite* sequence of stationary (sample) covariances into a linear stochastic system. Because of the finite covariance history, which is naturally defined on a finite time interval, it involves modeling of a class of random signals called *reciprocal processes*. At a general level this extension problem makes contact with a widely studied problem of Operator Theory called *Band Matrix Extension* which in this specific context is called *Covariance Extension*.

1. F. Carli, A. Ferrante, M. Pavon and G. Picci (2010), A Maximum Entropy solution of the Covariance Selection Problem for Reciprocal Processes. In: Hu, X.; Jonsson, U.; Wahlberg, B.; Ghosh, B. (Eds.) *Three Decades of Progress in Control Sciences* p. 77-93, Springer-Verlag, ISBN: 978-3-642-11277-5.

2. F. Carli, A. Ferrante, M. Pavon and G. Picci (2010), A Maximum Entropy approach to the Covariance Extension Problem for Reciprocal Processes, in *Proc. of the19th Int. Symposium on the Mathematical Theory of Networks and Systems (MTNS 2010)*, Budapest, Hungary, pp. 899-903, 2010.

3. F. Carli and G. Picci (2010), On the factorization approach to band extension of block-circulant matrices, in *Proc. of the19th Int. Symposium on the Mathematical Theory of Networks and Systems (MTNS 2010)*, Budapest, Hungary, pp. 907-914, 2010.

4. F. Carli, A. Ferrante, M. Pavon and G. Picci (2011), A Maximum Entropy approach to the Covariance Extension Problem for Reciprocal Processes, *IEEE Transactions on Automatic Control*, **56**: pp. 1999–2012, September 2011.

5. F. Carli, A. Ferrante, M. Pavon and G. Picci (2011), An Efficient Algorithm for Dempster's Completion of Block–Circulant Covariance Matrices, *Proc. 50th Decision and Control Conference (CDC)*, pp. 2963–2968, Orlando FLA, USA.

6. A. Lindquist and G. Picci, The Circulant Rational Covariance Extension Problem: The Complete Solution, *IEEE Transactions on Automatic Control*, vol **58**, pp 2848-2861 (2013).

7. F. Carli, A. Ferrante, M. Pavon and G. Picci (2013), An Efficient Algorithm for Maximum–Entropy Extension of Block–Circulant Covariance Matrices, *Linear Algebra and its Applications*, **439** pp 2309–2339, doi: 10.1016 j.laa.2013.06.014

8. A.Lindquist, C. Masiero and G. Picci, On the Multivariate Circulant Rational Covariance Extension Problem, *Proc of the 2013 Decision and Control Conference*, Florence, 2013, pp. 7155–7161.

9. G. Picci, A new approach to circulant band extension, *Proc of the 22nd Int. Symposium on the Mathematical Theory of Networks and Systems (MTNS 2016)*, Minneapolis, MN. July 2016, pp 123-130.

10. G. Picci and Bin Zhu, Approximation of Vector Processes by Covariance Matching with Applications to Smoothing, *IEEE Control Systems Letters*, vol 1 pp. 200-205, 2017.

11. Bin Zhu and G. Picci, Proof of Local Convergence of a New Algorithm for Covariance Matching of Periodic ARMA Models, *IEEE Control Systems Letters*, vol 1 pp. 206-211, 2017.

6 Vision-Based estimation and guidance

This project is centered on Kalman filter-based motion and scene estimation from visual sensing. There has been a close collaboration with the computer vision groups at UCLA (prof Soatto) and Caltech (prof Perona), and much joint work has resulted from the collaboration with these teams.

1. R.Frezza, G. Picci, P. Perona, S. Soatto, "System Theoretic Aspects of Dynamic Vision", in *Trends in Control*, A. Isidori ed., (invited paper presented at the 3rd European Control Conference, Rome, Italy, Sept. 1995), Springer Verlag, pp. 349 - 383 , 1995.

2. R.Frezza, G. Picci, "On line path following by recursive spline updating", (invited paper FP09) *Proceedings of the 34th Conference on Decision and Control*, New Orleans, IEEE Press, pp. 4047-4052, vol **4**, 1995.

3. G. Picci, "Dynamic Vision and Estimation on Spheres", *Proceedings of the 1997 Conference on Decision and Control*, San Diego Ca., p. 1140-1145, IEEE Press 1997.

4. R.Frezza, S. Soatto, G. Picci, "On-line path following by recursive spline updating", *Proceedings of the 1997 Conference on Decision and Control*, San Diego Ca, p. 1130-1135, IEEE Press, 1997.

5. A. Chiuso and G. Picci, "Visual Tracking of Points as Estimation on the Unit Sphere" in *The Confluence of Vision and Control*, D. Kriegman, G. Hager and S. Morse eds. Springer-Verlag Lecture Notes in Control and Information Systems (LNCIS) n. 237, pp. 90-105, 1998.

6. R Frezza, G. Picci and S. Soatto "A Lagrangian Formulation of Nonholonomic Path Following" in *The Confluence of Vision and Control*, D. Kriegman, G. Hager and S. Morse eds. Springer-Verlag Lecture Notes in Control and Information Systems (LNCIS) n. 237, pp. 118-133, 1998.

7. A. Chiuso and G. Picci, "A wide-sense estimation theory on the unit sphere", in *Proceedings of the 1998 Conference on Decision and Control*, Tampa, Florida, paper n. FM02-5, p. 3745-3750, 1998.

8. A. Chiuso, A. Ferrante, G. Picci (2005) Reciprocal realization and modeling of textured images" *Proc. of CDC-ECC05*, pp. 6059-6064, Sevilla, Spain.

9. A. Chiuso, G. Picci and S. Soatto, Wide sense estimation on the orthogonal group, *Communications in Information and Systems (the Brockett legacy special issue)*, **8**, pp. 185-200, (2008).

10. A. Chiuso and G. Picci, Some identification techniques in computer vision (invited paper), in *Proc. of the 47th IEEE Decision and Control Conference*, pp. 3935-3946, Cancun, Mex. Dec. 2008.

7 Discrete Mechanical Systems and their Identification

The models of mechanical systems are intrinsically continuous-time but for identification and simulation purposes they need to be discretized. Their discretization however is a delicate problem. J. Marsden and co-workers have approached the discretization of of mechanical systems from a completely new angle inventing from scratch a new theory of *Discrete Mechanics* based on first principles formulated in discrete-time. We use their approach for the identification of linear multivariable mechanical systems possibly with a large number of degree of freedom.

1. M. Bruschetta, G. Picci and A. Saccon (2009), Discrete Mechanical Systems: Second Order Modelling and Identification, *Proc of the 15th IFAC Sysmposium on System Identification (SYSID)*, pp. 456-461, St Malo, France, 2009.

2. M. Bruschetta, G. Picci and A. Saccon (2010), How to sample a linear mechanical system, in *Perspectives in Mathematical System Theory, Control, and Signal Processing*, J.C. Willems, S. Hara, Y. Ohta and H. Fujioka eds, Springer LNCiS series n. 398, pp 343-354 (2010).

3. M. Bruschetta, G. Picci and A. Saccon, A variational integrators approach to second order modeling and identification of linear mechanical systems, *Automatica* (full paper), **50**, pp. 727 – 736 (Available on line 26 Dec 2013).

8 Applied projects and Grants

Applied work which has resulted from several contracts with industries and research agencies has led to the implementation of stochastic filtering and modern control algorithms to marine systems, electric drives, and to autonomous mobile robots based on computer vision. My involvement in these industrial and applied scientific projects is described in the following list:

1. Principal investigator of the project *Design of single–point mooring control systems for large tankers*, 1984, contract with TECNOMARE S.p.A., Venice, Italy. Co–investigators G.B. Di Masi and L. Finesso.

2. Project manager and team leader of the italian team (IT-LADSEB) for the European Research Network of Excellence *System Identification* (ERNSI), funded by the Commission of the European Communities through the Human Capital and Mobility Program (HCM), formerly SCIENCE Project, started in 1992 and concluded in 1996.

3. Principal investigator of *Guidance and Control of Autonomous Vehicles based on Computer Vision*, reserch grant funded by the Italian Space Agency, (A.S.I.), Rome, awarded in 1992-93-94-95-97-99, co-investigators R. Frezza, P. Perona and S. Soatto. Some papers describing the work done in this area are listed above.

4. *Control of an underwater manipulator based on local image features*, 1994, TECNOMARE and SAIPEM SpA contract, co-investigator R. Frezza.

5. Project manager and team leader of the italian team (IT–LADSEB) for the European Research Network of Excellence *System Identification* (ERNSI), funded by the Commission of the European Communities through the Training and Mobility of Researchers Program (TMR), 1997-2003.

6. National coordinator and principal investigator of the University of Padova team, of the national research project *Identification and Control of Industrial Systems* funded by the italian ministery of higher education (MURST), 1998-2000.

7. National coordinator and principal investigator of the University of Padova team, of the national research project *Identification and Adaptive Control of Industrial Systems* funded by the italian ministery of higher education (MURST), 2000-2002.

8. National coordinator and principal investigator of the University of Padova team, of the national research project *New Algorithms for the Identification and Adaptive Control of Industrial Systems* funded by the italian ministery of university research (MIUR), 2002-2004.

9. Consultant for various industrial groups, among which Tecnomare S.p.A. Venice, Italy; Ferrari S.p.A. Maranello, Italy; SATE S.r.L. Venice,Italy; Salvagnini S.p.A. Vicenza, Italy; and others.

10. General Coordinator and principal investigator of the University of Padova team, of the reasearch cluster *Robotic Vision* for the Italian Space Agency, (A.S.I.), Rome, 1999-2000-2001.

11. General Project Coordinator and University of Padova team leader, of the European Community IST project *Real-time Embedded Control of Mobile Systems with Distributed Sensing (RECSYS)*, V-th Framework Programme, 2002-2005.

12. National coordinator and principal investigator of the University of Padova team, of the national research project *New Algorithms for the Identification and Adaptive Control of Industrial Systems* funded by the Italian Ministery of university research (MIUR), 2006-2008 and 2008-2012.

13. Consultant of the *Tethis-Protecno* agencies for the prediction of the lagoon levels in Venice in view of the operation of the *MOSE* dams. Co-investigator: Francesca Parise, 2012-2013. Work published in the paper:

    F. Parise and G. Picci, Identification of high tide models in the Venetian lagoon: variable selection and G-LASSO, *Proc of the 19th IFAC World Congress*, Capetown, South Africa, Aug. 2014, pp. 10385–10390.