

Part B.1 Individual Group Report (2003-2006)

(To be completed by the Principal Investigator on behalf of the group)

1. Group N^o (Automatic from table 10.1)

3

2. Name/Designation

Control Theory Group (cotg)

3. Location of Group if different from Host Institution (500 ca)

4. Principal Investigator (Automatic from table 10.1)

Delfim F. M. Torres

Public key: J001957OH25

5. Past, present and future location of Principle Investigator

(Indicate if the Principle Investigator carried out past research in a different Unit. Indicate if Principle Investigator will move to a different Research Unit)

Past Research Unit: **Centre for Research in Optimization and Control (CEOC)**

Present Research unit: **Centre for Research in Optimization and Control (CEOC)**

Future Research Unit: **Centre for Research in Optimization and Control (CEOC)**

6. Other researchers in the Group (PhD only) (Public key)

Alexander Plakhov (J019647V383)

Evgeny Lakshtanov (J0225464T0Y)

João Pedro Cruz (J024738XS9R)

Manuel Guerra (J02465926JU)

Moulay Rchid Sidi Ammi (J021763HKS)

Natália Martins (J024046TXWTQ)

Vítor Neves (J02203245U0)

7. Key words (4)

**calculus of variations and optimal control,
minimal resistance and mass transfer,
motivated applications & computational mathematics,
nonlinear control theory**

8. Funding, source, dates (1000 ca)

**2002-04, Nonlinear Systems and Control Network
European Commission, Research Training Network**

Coordinator: Françoise Lamnabhi-Lagarrigue, Centre National de la Recherche Scientifique, France

Total Funding: 1 500 kECU; see <http://www.supelec.fr/lss/NCN/>

**2002-05, Advances in Nonlinear Control and Calculus of Variations
FCT Sapiens'01, POCTI/MAT/41683/2001**

Coordinator: Vitor Manuel Carvalho das Neves; Total: 40 000 Euro

2004, Application of Conservation Laws to Space Trajectory, Actions Luso-Françaises (Univ. Aveiro & Univ. Paris XI)
Coordinators: Delfim F. M. Torres (Portugal), Emmanuel Trélat (France); Total: 2 000 Euro

2004-07, Analysis of Vibrations in Nonlinear Dynamical Systems, post-doc FCT, SFRH/BPD/14946/2004
Coordinator: Delfim F. M. Torres; Total: 1500 x 36 months = 54 000 Euro

2005, Marie Curie Control Training Site, HPMT-CT-2001-00278
Analytical solutions to magnetohydrodynamical control problems on a flow of conducting fluid
Coordinator: Delfim F. M. Torres; Total: 2 800 Euro

2005-06, Marie Curie Control Training Site, HPMT-CT-2001-00278
Impedance Change and the Calculus of Variations
Coordinator: Delfim F. M. Torres; Total: 8 400 Euro

2005-07, Differential Inclusions and Variational Problems
Project POCI/MAT/55524/2004
Coordinator: Vasile Staicu, Univ. Aveiro; Total: 25 500 Euro

2005-08, Thermistor Problems and Optimal Control, post-doc FCT, SFRH/BPD/20934/2004
Coordinator: Delfim F. M. Torres; Total: 1500 x 36 months = 54 000 Euro

2005-08, Towards the Quantum Problem of the Body of Least Resistance, post-doc FCT, SFRH/BPD/21009/2004
Coordinator: Alexander Plakhov; Total: 1500 x 36 months = 54 000 Euro

9. Objectives (2000 ca)

To study minimal resistance and mass transfer problems (including the study of the classical Newtonian problem of the body of least resistance in various classes of bodies: non-convex axisymmetric and non-axisymmetric bodies, two- and three-dimensional cases, with and without restrictions imposed on the maximal number of collisions of particles with the body; minimization of specific resistance of infinite surfaces; minimization of resistance to bodies moving in a medium of positive temperature; relationship between the problem of minimal resistance of non-convex rotating bodies and the one-dimensional problem of mass transfer; relationship between linear transport and mass transfer problems); to obtain new versions of Pontryagin's maximum principle covering classes of generalized controls (to give geometric characterizations of generalized extremals and accessible sets; to investigate singular optimal control problems); to obtain conditions for boundedness of optimal controls; to investigate the role of symmetry and conservation laws in the calculus of variations and optimal control (extension of Noether's theorem of the calculus of variations to the wider class of Lipschitz functions; to obtain conserved quantities along all minimizers of the problems); to identify new and more general classes of well and bad behaved problems in the calculus of variations and optimal control; to develop a computer algebra package for determining symmetries and conservation laws in the calculus of variations and optimal control; to develop numerical and asymptotical methods to study nonlinear dynamical control systems with distributed and discrete parameters, decreasing the effect of vibrations; to apply hyperfinite discretization and non-standard hull methods in critical point theory as well as to control in differentiable manifolds.

10. Main achievements (2000 ca)

Proof that resistance for Newton problems with multiple collisions can be made less than any positive number; solution of the minimal resistance problem per unit surface area; estimates for rough bodies with and without rotation; exact solutions for the Monge-Kantorovich problem in one dimension; classification of optimal shapes in a thermal motion media; universal solution in the infinite-temperature limit; formulation of the wave (quantum) analogue of the minimal resistance problem; resistance of the hard sphere for all values of frequencies; proof that at high frequencies the quantum resistance of a convex hard body tends to the classical one and for small positive values of frequencies the resistance is less than the total cross section of the body; proof that a wide range of optimal resistance problems in dimension two can be reduced to a one-dimensional Monge-Kantorovich problem. Characterization of generalized extremals and attainable sets for control-affine systems; proof that Orlov's conjecture [Unsolved Problems in

[Mathematical Systems and Control Theory, V. Blondel & A. Megretski \(eds\), Princeton Univ Press, 2004\]](#) admits, in general, a positive answer, independently of commutativity for the controlled fields; [new index to measure the singular behavior of minimizing sequences for control-affine control problems; fully characterization of asymptotics of minimizing sequences for singular linear-quadratic problems. Nonstandard Palais-Smale conditions and Mountain Pass theorems; existence and location of critical points to functionals on Banach spaces and global analysis of hulls, with applications to optimal problems. Noether's theorem for: multiobjective control problems, nonconservative dynamical optimal control systems, fractional variational problems. Method to generate effective first integrals for nonlinear control systems, connecting Noether's and Kozlov-Kolesnikov theorems; computational tool to symmetries and conservation laws in optimal control.](#)

11. Publications in peer review Journals (3000 ca) (Up to max of 10. If available indicate at the end of the citation, impact factor of the Journal (IP=..) and number of citations (n° C =...)). Give title and full citation in original language. DO NOT translate)

[Remark: We only mention publications in the period 2003-2006.](#)

2003

Delfim F. M. [Torres](#),

Lipschitzian Regularity of the Minimizing Trajectories for Nonlinear Optimal Control Problems,

Mathematics of Control, Signals, and Systems, Vol. 16, 2003, pp. 158-174.

[Impact Factor \(ISI\): \[1.156 \(2001\); 0.844 \(2002\); 0.742 \(2003\); 0.393 \(2004\)\]](#)

[n° C = 2](#)

2004

A. Yu. [Plakhov](#),

Precise solutions of the one-dimensional Monge-Kantorovich problem,

Sbornik: Mathematics, 195, No9 (2004): 1291-1308.

[Impact Factor \(ISI\): \[0.419 \(2002\); 0.353 \(2003\); 0.453 \(2004\)\]](#)

A. Yu. [Plakhov](#),

Newton's problem of minimal resistance for bodies containing a half-space,

J. Dynam. Control Syst., Vol. 10, No. 2, 2004, pp. 247-251.

[Impact Factor \(ISI\): \[0.396 \(2004\)\]](#)

Delfim F. M. [Torres](#),

Proper Extensions of Noether's Symmetry Theorem for Nonsmooth Extremals of the Calculus of Variations,

Communications on Pure and Applied Analysis, Vol. 3, No. 3, 2004, pp. 491-500.

[Impact Factor \(ISI\): \[0.581 \(2003\); 0.618 \(2004\)\]](#)

2005

Alexander Yu. [Plakhov](#) and Delfim F. M. [Torres](#),

Newton's aerodynamic problem in media of chaotically moving particles,

Sbornik: Mathematics, Vol. 196 (2005), No. 6, pp. 885-933.

[Impact Factor \(ISI\): \[0.419 \(2002\); 0.353 \(2003\); 0.453 \(2004\)\]](#)

Olena V. Mul and Delfim F. M. [Torres](#),

Analysis of Vibrations in Large Flexible Hybrid Systems,

Nonlinear Analysis - Theory, Methods & Applications, Vol. 63, Issue 3, 2005, pp. 350-363.

[Impact Factor \(ISI\): \[0.406 \(2001\); 0.314 \(2002\); 0.354 \(2003\); 0.459 \(2004\)\]](#)

2006

A. I. Aleksenko, W. de Roeck and E. L. [Lakshtanov](#),

Note on the transport cross-section,

J. Phys. A: Math. Gen. V.39, 2006: 1-5.

[Impact Factor \(ISI\): \[1.406 \(2002\); 1.357 \(2003\); 1.504 \(2004\)\]](#)

E. L. [Lakshtanov](#), S. A. Pirogov, and A. I. Aleksenko,

One- and two-particle bound states in the Landau quantum liquid model,

Lett. Math. Phys. V.77 (1), 2006: 83-98.

[Impact Factor \(ISI\): \[0.812 \(2002\); 0.709 \(2003\); 0.926 \(2004\)\]](#)

A. Yu. [Plakhov](#),

Billiards in unbounded domains reversing the direction of motion of a particle,

Russ. Math. Surv. V.61, 2006: 179-180.

[Impact Factor \(ISI\): \[0.455 \(2002\); 0.418 \(2003\); 0.393 \(2004\)\]](#)

Paulo D. F. Gouveia, Delfim F. M. [Torres](#) and Eugénio A. M. Rocha,

Symbolic Computation of Variational Symmetries in Optimal Control,

Control and Cybernetics, Vol. 35 (2006), No. 4, pp. 831-849.

[Impact Factor \(ISI\): \[0.326 \(2002\); 0.101 \(2003\); 0.337 \(2004\)\]](#)

12. Other publications (3000 ca) (Include only Books, chapters or full papers published in conference proceedings up to max of 10. Give title and full citation in original language)

Remark: We only mention publications in the period 2003-2006.

2003

Manuel Guerra, On nonautonomous singular L-Q problems, Lagrangian and Hamiltonian Methods in Nonlinear Control (Editors: A. Astolfi, F. Gordillo, A. van der Schaft) IFAC Workshop Series, 2003, pp. 189-194.

2004

Manuel Guerra, Distribution-like Hamiltonian flows and generalized optimal controls, Journal of Mathematical Sciences (Series of Contemporary Mathematics and Its Applications, Special volume "Aveiro Seminar on Control, Optimization, and Graph Theory"), N.Y. (USA), Vol. 120, N. 1, (2004): 895-918.

Vítor Neves, Nonstandard Calculus of Variations - a survey, Journal of Mathematical Sciences (Series of Contemporary Mathematics and Its Applications, Special volume "Aveiro Seminar on Control, Optimization, and Graph Theory"), N.Y. (USA), Vol. 120, N. 1, (2004): 940-954.

T. Kudryk, W. Lyantse, Vítor Neves, Nonstandard Universe based on Internal Set Theory, Proc. of the Int. Conference on Functional Analysis and Applications dedicated to the 110th anniversary of Stefan Banach, May 2002. North-Holland Math. Studies n. 197, 2004.

Alexander Plakhov and Pedro Cruz, A stochastic approximation algorithm with step size adaptation, Journal of Mathematical Sciences, Series of Contemporary Mathematics and Its Applications, Special volume "Aveiro Seminar on Control, Optimization, and Graph Theory", N.Y. (USA), 120, N.1, (2004): 964-973

2005

Pedro Cruz, Speeding up backpropagation with multiplicative batch update step, International Conference on Adaptive and Natural Computing Algorithms. In: B. Ribeiro, R.F. Albrecht, A. Dobnikar, D.W. Pearson, N.C. Steele (Eds.), (2005): pp. 22-24, Springer, New York, (ISBN: 3-211-24934-6).

Manuel Guerra, Discontinuous Hamiltonian flows for nonlinear control systems, Proc. 2nd Junior European Meeting on "Control Theory and Stabilization", Rend. Sem. Mat. Univ. Pol. Torino. Vol 64, No 4, (2005): 363-382.

Natália Martins and Vítor Neves, Nonstandard discrete derivatives and existence theorems for ODEs, Proc. 2nd Junior European Meeting on "Control Theory and Stabilization", Rend. Sem. Mat. Univ. Pol. Torino. Vol. 63, No 4 (2005): 383-395.

2006

Abderrahmane El Hachimi, Moulay Rchid Sidi Ammi, Delfim F. M. Torres, Existence and uniqueness of solutions for a nonlocal parabolic thermistor-type problem, Proc. 13th IFAC Workshop on Control Applications of Optimisation (CAO'06), 26-28 April 2006, ENS de Cachan, Paris, pp. 407-411.

Gastão S. F. Frederico and Delfim F. M. Torres, Noether's theorem for fractional optimal control problems, Proceedings of the 2nd IFAC Workshop on Fractional Differentiation

and its Applications, 19-21 July 2006, Porto, pp. 142-147.

13. Master and PhD thesis completed (3000 ca)

MSc dissertations

Cristiana João Soares da Silva,
"Abordagens do Cálculo das Variações e Controlo Óptimo ao Problema de Newton de Resistência Mínima",
Mestrado em Matemática – Análise e Geometria, Universidade de Aveiro, 2005 (supervisor: Delfim F. M. [Torres](#)).

Susana Raquel da Silva Leal Pereira,
"Integrabilidade e dispersão de sistemas Hamiltonianos",
Universidade de Aveiro, 2005 (supervisor: Alexander [Plakhov](#)).

Andreia Marques Freitas Louro,
"Computação Simbólica em Maple no Cálculo das Variações",
MSc on Mathematics, University of Aveiro, 2006 (supervisor: Delfim F. M. [Torres](#)).

Joana Freitas da Costa,
"Teorema de Noether do Cálculo das Variações e Controlo Óptimo na Economia",
MSc on Mathematics, University of Aveiro, 2006 (supervisor: Delfim F. M. [Torres](#)).

PhD theses

Pedro Cruz,
"Stochastic Approximation Algorithms with Adaptive Step Value",
PhD Thesis, University of Aveiro, 2005 (supervised by Alexander [Plakhov](#)).

Natália Martins,
"Some applications of non-standard analysis to critical point theory and differential equations",
PhD Thesis in Mathematics, University of Aveiro, 2006
(supervised by Vitor [Neves](#) and Maria João Borges from Technical University of Lisbon).

14. Patents/prototypes (2000 ca)

15. Organization of conferences (2000 ca)

2003

Second Junior European Meeting on "Control Theory and Stabilization",
Dipartimento di Matematica del Politecnico di Torino, Torino, Italy, 3-5 December 2003.
(Member of the Organizing Committee: Delfim F. M. [Torres](#))

2004

Nonstandard Mathematics 2004, Dep. of Math., Aveiro, Portugal, July 5 to 10, 2004.
(Members of the Organizing Committee: N. [Martins](#) and V. [Neves](#) (Chairman))

First Control Training Site Workshop (1stCTSW),
Department of Mathematics, University of Coimbra, 1-3 July 2004, Portugal
(Members of the Organizing Committee: M. [Guerra](#) and D. [Torres](#))

3rd Junior European Meeting on "Control, Optimization, and Computation",
University of Aveiro, 6-8 September 2004, Portugal
(Members of the Organizing Committee: M. [Guerra](#), N. [Martins](#), D. [Torres](#) (Chairman))

2005

4th Junior European Meeting on "Control and Optimization",
Bialystok, Poland, Sep. 11--14, 2005
(Delfim F. M. [Torres](#) was member of the Scientific Committee)

2006

13th IFAC Workshop on "Control Applications of Optimization" (CAO'06),

Paris - Cachan, France, April 26-28, 2006
(Delfim F. M. [Torres](#) was member of the Organizing Committee,
editing with Emmanuel Trélat the conference proceedings)

16. Industry contract research (2000 ca)

17. Internationalization (2000 ca) (Collaborative publications, Research and Graduate Training Networks)

In the period 2003-06 cotg members had co-authors from 13 different foreign countries: Belgium, Cape Verde, France, Georgia, Italy, Latvia, Morocco, Poland, Romania, Russia, South Korea, Suisse, and Ukraine.

Under the European Research and Graduate Training Network "Control Training Site" (CTS), 2 PhD students from Riga Technical University were supervised:

I. Dzenite, 2 Marie Curie Fellowships: HPMT-GH-01-00278-109 (Jan. to July 2005);
HPMT-GH-01-00278-150 (Sept. 2005 to March 2006);

E. Ligere, Marie Curie Fellowship HPMT-GH-01-00278-136 (March to July 2005).

In the period 2003-06 more than 22 foreign mathematicians visited cotg members:

Z. Bartosiewicz (Bialystok Technical Univ, Poland);
J. M. Borwein (Dalhousie Univ, Canada);
U. Boscain (SISSA, Italy);
G. Buttazzo (Univ Pisa, Italy);
J. Clemente-Gallardo (Univ Zaragoza, Spain);
M. Comte (Univ Paris VI, France);
B. N. Datta (Northern Illinois Univ, USA);
A. Davydov (Vladimir State Univ, Russia);
W. De Roeck (Catholic Univ of Leuven, Belgium);
A. Hamel (Martin-Luther Univ, Germany);
M. Kowski (Arizona State Univ, USA);
T. Lachand-Robert (Univ of Savoie, France);
V. Levin (CEMI, Moscow);
A. B. Malinowska (Bialystok Technology Univ, Poland);
R. McCann (Univ Toronto, Canada);
B. Miller (Russian Academy of Sciences, Russia);
A. Sarychev (Univ Firenze, Italy);
V. Sesadze (Georgian Technical Univ, Georgia);
M. Shvartsman (Univ. St. Thomas, USA);
A. Stepin (Moscow State Univ, Russia);
E. Trélat (Univ Paris-Sud XI, France);
I. Volodko (Riga Technical Univ, Latvia).

Cotg members made several visits to foreign universities and research institutions, including:

Georgia Tech, USA;
International School for Advanced Studies, Italy;
University of Pisa, Italy;
Università degli Studi di Firenze, Italy;
SISSA, Italy;
Georgian Technical University, Georgia;
University Paris XI, France;
University of Savoie, France;
Adam Mickiewicz University, Poland;
Bialystok Technical University, Poland;
Riga Technical University, Latvia;
Ternopil University of National Economy, Ukraine.