

Scientific Report 2005

Control Theory Group (cotg)
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March 2006

Members of the Control Theory Group

- **Senior Researchers**

1. Delfim F. M. Torres (cotg Coordinator)
2. Eugénio Rocha
3. Manuel Guerra

- **Post-Docs**

1. Moulay Rhid Sidi Ammi
2. Olena V. Mul

- **PhD Students**

1. Paulo D. F. Gouveia

- **Other Students**

1. Cristiana Silva, MSc student
2. Elena Ligere, PhD student at Riga Technical University, Latvia (with the University of Aveiro from March to July 2005, Marie Curie Fellowship)
3. Gastão S. F. Frederico, Fellowship from IPAD, Instituto Português de Apoio ao Desenvolvimento
4. Iona Dzenite, PhD student at Riga Technical University, Latvia (with the University of Aveiro from Jan 2005 to March 2006, Marie Curie Fellowship)
5. Rita Gaspar, MSc student

Activities during 2005

Manuel Guerra has done progress in the study of singular control systems and generalized controls. Results characterizing the attainable set for control-affine systems have been obtained. In collaboration with Andrei Sarychev (University of Florence, Italy), results were obtained concerning minimizing sequences for singular optimal control-affine problems. A conjecture formulated by Yu. Orlov [in: Vincent D. Blondel & Alexandre Megretski (ed.) *Unsolved Problems in Mathematical Systems and Control Theory*, Princeton University Press, (2004)] was addressed. The asymptotics of minimizing sequences for singular linear-quadratic problems were fully characterized. Partial results concerning the asymptotics of generic problems were obtained (manuscript in preparation).

Eugénio Rocha, in cooperation with D. Torres, has studied: (i) methods to generate effective first integrals for general nonlinear control systems, building a bridge between Noether's theorem and the Kozlov-Kolesnikov theorem; (ii) unidimensional problems of Calculus of Variations on locally convex spaces. Together with D. Torres and P. Gouveia, Eugénio Rocha has studied the symbolic implementation of an algorithm to obtain effective first integrals; with J.F.Rodrigues has worked in some fields of mathematical knowledge management.

Delfim Torres has proved: (i) a Noether-type symmetry theorem for invariant optimal control problems with unrestricted controls. The result establishes weak conservation laws along all the minimizers of the problems, including those minimizers which do not satisfy the Pontryagin Maximum Principle; (ii) a version of Noether's invariance theorem for optimal control problems with a finite number of cost functionals. The result is obtained by formulating E. Noether's result to optimal control problems subject to isoperimetric constraints, and then using the unimprovable (Pareto) notion of optimality. A result of this kind was posed, as a mathematical open question, of great interest in applications of control engineering, by A. Gugushvili; (iii) with Gastão S. F. Frederico, an extension of Noether's theorem to dynamical optimal control systems being under the action of nonconservative forces. A systematic way of calculating conservation laws for nonconservative optimal control problems was given. As a corollary, the conserved quantities previously obtained in the literature for nonconservative problems of mechanics and the calculus of variations are derived.

As part of Paulo Gouveia PhD thesis, we obtained analytic computational tools that permit us to identify, in an automatic way, conservation laws in optimal control. The central result we use is the famous Noether's theorem, a classical theory developed by Emmy Noether in 1918, in the context of the calculus of variations and mathematical physics, and which was extended recently to the more general context of optimal control. We show how a Computer Algebra System can be very helpful in finding the symmetries and corresponding conservation laws in optimal control theory, thus making useful in practice the theoretical results recently obtained in the literature. A Maple package was implemented and several illustrative examples given.

As part of the post-doc of Dr. Olena V. Mul, the mathematical model of a

real flexible elastic system with distributed and discrete parameters was considered. It is a partial differential equation with non-classical boundary conditions. Complexity of the boundary conditions make it impossible to find exact analytical solutions. To address the problem, we used the asymptotical method of small parameters together with the numerical method of normal fundamental systems of solutions. These methods allow us to investigate vibrations, and a technique for determination of complex eigenvalues of the considered boundary value problem was developed. The conditions, at which vibration processes of different characteristics take place, were defined. The dependence of the vibration frequencies on the physical parameters of the hybrid system was studied. We show that introduction of different feedbacks into the system allows one to control the frequency spectrum, in which excitation of vibrations is possible.

As part of the post-doc of Dr. Moulay Rchid Sidi Ammi, a spatially semi-discrete finite element method was proposed for a non-local parabolic problem arising in ohmic heating. An error analysis was given.

Members of *cotg* have participated in the following projects: “Advances in Nonlinear Control and Calculus of Variations” (POCTI/MAT/41683/2001); “Inclusões Diferenciais e Problemas Variacionais” (POCTI/MAT/55524/2004); Control Training Site (CTS, Marie Curie Fellowships).

Delfim Torres was the CTS Host supervisor of PhD students Ilona Dzenite and Elena Ligere, from Riga Technical University, Latvia.

During 2005 Scientific Cooperation took place with: Riga Technical University, Latvia; Bialystok Technical University, Poland; Université Paris-Sud XI, Orsay, France.

Several Seminars were given by the members of the group in different Universities.

A mini-course on “State-of-the Art Computational Methods and Software for Control Systems”, with lectures given by Biswa Nath Datta, Department of Mathematical Sciences, Northern Illinois University, USA, was organized at the University of Aveiro, 14-15 December 2005.

Several informal working meetings took place during 2005.

In 2005, the following researchers, with joint research interests with members of the *cotg*, visited the Department of Mathematics: Zbigniew Bartosiewicz, Technical University of Bialystok, Poland, July 18-23, 2005; Prof. Biswa Nath Datta, Northern Illinois University, Department of Mathematical Sciences De Kalb, Illinois, USA, December 13-19, 2005.

Members of *cotg* made several visits to foreign universities and research institutions: Riga Technical University, Latvia (March 2005); Dipartimento di Matematica per le Decisioni, Università degli Studi di Firenze, Italy (April 2005); Ternopil University of National Economy, Ukraine (June 2005); Białystok Technical University, Poland (November 2005); Faculty of Mathematics and Computer Science, Adam Mickiewicz University, Poznań, Poland (December 2005).

Output indicators

Number of Publications	2005
Books	0
Papers in international journals	6
Papers in national journals	2
Number of Communications	
in International Meetings	11
in National Meetings	6
Reports	12
Organization of seminar and conferences	11
Advanced training	
number of PhD theses	0
number of Master theses	1

List of publications

- **Articles in International Journals (including book chapters)**

1. Delfim F. M. Torres, Viorica Teca. *Consecutive, Reversed, Mirror, and Symmetric Smarandache Sequences of Triangular Numbers*, Scientia Magna, Vol. 1 (2005), No. 2, 39–45. [Zbl pre05008769]
2. Manuel Guerra. *Discontinuous Hamiltonian flows for nonlinear control systems*. Rend. Sem. Mat. Univ. Pol. Torino. Vol 64 No 4, 2005, pp 363-382. <http://seminariomatematico.dm.unito.it/rendiconti/63-4/363.pdf>
3. Olena V. Mul, Delfim F. M. Torres. *A Numerical Method for the Investigation of Vibrations in Large Flexible Systems*, International Scientific Journal of Computing, Vol. 4, Issue 1, 2005, pp. 52–59.
4. Olena V. Mul, Delfim F. M. Torres. *Analysis of Vibrations in Large Flexible Hybrid Systems*, Nonlinear Analysis, Volume 63, Issue 3, 1 November 2005, pages 350–363. [Zbl 1074.35064] [MR2167727] [ISI]
5. Paulo D. F. Gouveia, Delfim F. M. Torres. *Computation of Conservation Laws in Optimal Control*, Proceedings of the 10th International Conference Mathematical Modelling (MMA2005) and 2nd International Conference Computational Methods in Applied Mathematics (CMAM2), Trakai, Lithuania, 1-5 June 2005. In: Mathematical Modelling and Analysis, R. Čiegis (Ed.), 2005 Technika ISBN 9986-05-924-0, Vilnius, 2005, pp. 389–394. [MR 2194696]
6. Paulo D. F. Gouveia, Delfim F. M. Torres. *Automatic Computation of Conservation Laws in the Calculus of Variations and Optimal Control*, Computational Methods in Applied Mathematics, Vol.5, No.4, 2005, pp. 387–409. [Zbl 1079.49019] [MR 2194205]

- **Articles in National Journals**

1. Eugénio Rocha, José Francisco Rodrigues. *Comunicação da Matemática na Era Digital*, Boletim da Sociedade Portuguesa de Matemática #53, October 2005, pp. 1-21.
2. Paulo D. F. Gouveia, Delfim F. M. Torres. *Computação Algébrica no Cálculo das Variações: determinação de simetrias e leis de conservação*, TEMA Tendências em Matemática Aplicada e Computacional, Vol. 6, 2005, Number 1, pp. 81–90.

List of talks

- **Talks at International Conferences**

1. Cristiana J. Silva, *Newton's Problem of Minimal Resistance in arbitrary dimension*, 4th Junior European Meeting on “Control and Optimization”, Department of Mathematics, Institute of Mathematics and Physics, Białystok Technical University, 2005 September, Białystok, Poland
2. Delfim F. M. Torres, *A Noether Theorem on Unimprovable Conservation Laws for Vector-Valued Optimization Problems in Control Theory*, First International Conference on Modeling, Simulation and Applied Optimization (ICMSAO'05), February 1-3 2005, American University of Sharjah, United Arab Emirates, 2005
3. Delfim F. M. Torres, *Scientific Computation of Conservation Laws in the Calculus of Variations and Optimal Control*, 10th International Conference Mathematical Modelling and Analysis (MMA2005) and 2nd International Conference Computational Methods in Applied Mathematics (CMAM05), 1-5/June/05, June 2005, Trakai, Lithuania
4. Delfim F. M. Torres, *Weak Conservation Laws for Minimizers which are not Pontryagin Extremals*, 2nd International Conference “Physics and Control” (PhysCon 2005), 24-26/08/2005, Saint Petersburg, Russia
5. Delfim F. M. Torres, *Symbolic Computation of Symmetries and Conservation Laws in Optimal Control*, 4th Junior European Meeting on Control and Optimization, Białystok Technical University, September 11–14 2005, Białystok, Poland
6. Eugénio A. M. Rocha, *First Integrals for Problems of the Calculus of Variations on Locally Convex Spaces*, OTFUSA'2005, International Conference on Operator Theory, Function Spaces and Applications, dedicated to the 60th birthday of Professor F.-O. Speck, 7–9 July 2005, Aveiro

7. Eugénio A. M. Rocha, *Quadratures of Pontryagin Extremals of some Optimal Control Problems*, 4th Junior European Meeting on "Control and Optimization", Department of Mathematics, Institute of Mathematics and Physics, Białystok Technical University, September 11–14 2005, Białystok, Poland
8. Ilona A. Dzenite, *A Remark on Noether's Theorem of Optimal Control*, 10th International Conference Mathematical Modelling and Analysis, June 1 - 5, 2005, Trakai, Lithuania
9. Manuel Guerra. *Generalized trajectories for affine control systems*. 4th Junior European Meeting on "Control and Optimization", Institute of Mathematics and Physics of the Białystok Technical University, Poland, September 11-14, 2005;
10. Moulay Rchid Sidi Ammi, *A spatially semi discrete finite element method for a non local parabolic problem*, Huitièmes Journées d'analyse Numérique et Optimisation, ENIM Rabat Maroc, 14-16 December 2005
11. Olena V. Mul, *On Asymptotical Method for Vibrations Analysis of Large Elastic Dynamical Systems*, Sixth International Conference "Symmetry in Nonlinear Mathematical Physics", June 20-26, 2005, Institute of Mathematics, National Academy of Sciences of Ukraine, Kyiv (Kiev), Ukraine

• **Talks at National Meetings**

1. Delfim F. M. Torres, *Descobrir o Maple*, Escola Secundária Homem Cristo, Aveiro, 19/January/2005
2. Delfim F. M. Torres, *Leis de Conservação de Pareto para problemas de Controlo Óptimo Multicritério*, Encontro Optimização e Controlo Óptimo CEOC (Aveiro) – CIMA-UE (Évora) 2005, Abril 22-23 2005, Évora
3. Delfim F. M. Torres, *Variations around the Deductive Approach in Optimal Control*, Socrates-Erasmus & Polish Mathematical Society Lecture, Białystok Technical University, 29-Nov-2005, Poland
4. Eugénio A. M. Rocha, *Método de redução para geodésicas sub-Riemannianas num grupo de Lie nilpotente*, Encontro Optimização e Controlo Óptimo CEOC (Aveiro) – CIMA-UE (Évora) 2005, Abril 22-23 2005, Évora
5. Eugénio A. M. Rocha, *Calculus and representation of flows of nonautonomous ODEs*, Socrates-Erasmus & Polish Mathematical Society Lecture, Białystok Technical University, 28-Nov-2005, Poland
6. Manuel Guerra, *Nonlinear control systems with high-order impulses*. Encontro Optimização e Controlo Óptimo CEOC (Aveiro) – CIMA-UE (Évora) 2005, Abril 22-23 2005, Évora

List of reports (including proceedings)

1. Abderrahmane El Hachimi, Moulay Rchid Sidi Ammi, Delfim F. M. Torres. *A spatially semi discrete finite element method for a non local parabolic problem*, Proceedings of the Huitièmes Journées d'analyse Numérique et Optimisation, ENIM Rabat, Maroc, 14–16 December 2005, pp. 317–322.
2. Abderrahmane El Hachimi, Moulay Rchid Sidi Ammi, Delfim F. M. Torres. *Existence and uniqueness of solutions for a nonlocal parabolic thermistor-type problem*, Research report CM05/I-55, Dep. Mathematics, Univ. Aveiro, December 2005. [PAM: handle/2052/109] [arXiv.org:math.AP/0512629] Accepted (19-12-2005) Proc. 13th IFAC Workshop on Control Applications of Optimisation, 26-28 April 2006, Paris - Cachan, France. IFAC publication, Elsevier Ltd, Oxford, UK.
3. Cristiana J. Silva, Delfim F. M. Torres. *On the Classical Newton's Problem of Minimal Resistance*. Third Junior European Meeting on Control, Optimization, and Computation, University of Aveiro, 6-8 September 2004, Portugal. M. Guerra and D.F.M. Torres eds., Research report CM05/I-04, Dep. Mathematics, Univ. Aveiro, February 2005, pp. 125–133.
4. Delfim F. M. Torres. *A Noether Theorem on Unimprovable Conservation Laws for Vector-Valued Optimization Problems in Control Theory*, Conference Proceedings of ICMSAO'05 – First International Conference on Modeling, Simulation and Applied Optimization, paper ID: 131, February 1-3 2005, American University of Sharjah, United Arab Emirates, 2005 (ISBN: 9948-427-00-9).
5. Delfim F. M. Torres. *Weak Conservation Laws for Minimizers which are not Pontryagin Extremals*, Proceedings of the 2005 International Conference “Physics and Control” (PhysCon 2005, edited by A.L. Fradkov and A.N. Churilov), August 24-26, 2005, Saint Petersburg, Russia, 2005 IEEE, pp. 134–138. ISBN 0-7803-9235-3, IEEE Catalog Number 05EX1099C. [ISI]
6. Delfim F. M. Torres. *Lipschitzian Regularity of the Minimizing Trajectories in the Calculus of Variations and Optimal Control: a Survey*. Third Junior European Meeting on Control, Optimization, and Computation, University of Aveiro, 6-8 September 2004, Portugal. M. Guerra and D.F.M. Torres eds., Research report CM05/I-04, Dep. Mathematics, Univ. Aveiro, February 2005, pp. 151–160.
7. Delfim F. M. Torres, Rita M. R. Pereira. *Computação Matemática Elementar em Máxima*, Cadernos de Matemática CM05/D-02, Dep. Mathematics, Univ. Aveiro, January 2005. [PAM: handle/123456789/28]
8. Eugénio A. M. Rocha, Delfim F. M. Torres. *First Integrals for Problems of the Calculus of Variations on Locally Convex Spaces*, Research report

CM05/I-32, Dep. Mathematics, Univ. Aveiro, July 2005. [PAM: handle/2052/83] [arXiv.org:math.OC/0511347]

9. Eugénio A. M. Rocha, Delfim F. M. Torres. *Quadratures of Pontryagin Extremals for Optimal Control Problems*, Research report CM05/I-48, Dep. Mathematics, Univ. Aveiro, November 2005. Accepted (17-03-2006) to the journal *Control and Cybernetics*.
10. Gastão S. F. Frederico, Delfim F. M. Torres. *Nonconservative Noether's Theorem in Optimal Control*, Research report CM05/I-54, Dep. Mathematics, Univ. Aveiro, December 2005. Accepted (19-12-2005) Proc. 13th IFAC Workshop on Control Applications of Optimisation, 26-28 April 2006, Paris - Cachan, France. IFAC publication, Elsevier Ltd, Oxford, UK.
11. Ilona A. Dzenite, Delfim F. M. Torres. *A Remark on Noether's Theorem of Optimal Control*, Research report CM05/I-23, Dep. Mathematics, Univ. Aveiro, June 2005. [PAM: handle/2052/72]
12. Manuel Guerra, Delfim F. M. Torres (editors). *Third Junior European Meeting on Control, Optimization, and Computation*, Research Report CM05/I-04, February 2005 (194 pages). [PAM: handle/123456789/35]

List of organized seminars and conferences

- **Organized seminars**

1. Olena V. Mul, (Post-doc at University of Aveiro), *Analysis of Vibrations in Large Flexible Hybrid Systems*, Seminários CEOC, Dep. Mathematics, Univ. Aveiro, February 11, 2005.
2. Delfim F. M. Torres, *Leis de Conservação para minimizantes mal comportados do Cálculo das Variações e Controlo Óptimo*, Seminários CEOC, Dep. Matemática, Univ. Aveiro, 08 Abril 2005
3. Olena V. Mul (Post-doc at University of Aveiro), Academy of National Economy, Ukraine, *Analysis of Vibrations in Some Machine Units With Discrete Parameters*, April 15, 2005
4. Gastão S. F. Frederico, *Teorema de Noether Não-Conservativo em Controlo Óptimo*, Seminários CEOC, Dep. Mathematics, Univ. Aveiro, April 29, 2005
5. Zbigniew Bartosiewicz, *Control theory on time scales*, Technical University of Bialystok, Poland, July 20, 2005
6. Rachid Sidi Ammi (Post-doc at University of Aveiro), *Some results concerning the thermistor Problem*, October 14, 2005
7. Joana Nunes da Costa, *Estruturas de Dirac e algebróides de Lie*, Universidade de Coimbra, November 11, 2005

8. Jonathan M. Borwein, *Maximizing Surprise*, Dalhousie University, Canada, November 25, 2005
9. Paulo D. F. Gouveia, *Computação Simbólica de Leis de Conservação no Cálculo das Variações e Controlo Ótimo – proposta de um novo package de funções para o Maple*, Seminários CEOC, Dep. Mathematics, Univ. Aveiro, 9/December/2005
10. Biswa Nath Datta, IEEE Fellow Distinguished Research Professor, Northern Illinois University, Department of Mathematical Sciences De Kalb, Illinois 60115, USA, *Recent Advances on Computational Methods for Structured Inverse Eigenvalue problems for Quadratic Matrix & Operator Pencils: Linking Mathematics to Industries*, December 16, 2005

- **Organized conferences**

1. Delfim F. M. Torres was member of the Scientific Committee of the 4th Junior European Meeting on “Control and Optimization”, Białystok, Poland, Sep. 11–14, 2005

List of MSc dissertations

1. Cristiana João Soares da Silva, *Abordagens do Cálculo das Variações e Controlo Ótimo ao Problema de Newton de Resistência Mínima* (Supervisor: Delfim F. M. Torres), Mestrado em Matemática (Análise e Geometria), 2005. [PAM: handle/2052/69]