

# CEOC

**Centro de Estudos em Optimização e Controlo**  
(Centre for Research in Optimization and Control)

Research Report 2006

**Universidade de Aveiro**  
**Departamento de Matemática**



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## Researchers and global output indicators of CEOC

### CEOC researchers

Name	Member type	Public Key	%
Domingos Moreira Cardoso	Coordinator	J02357833N8	40%
Agostinho Agra	Senior researcher	J024060A9WU	30%
Alexander Plakhov	Subproject coordinator	J019647V383	40%
Antonio Leslie Bajuelos Dominguez	Senior researcher	J0010901FT8	30%
Carlos J. Luz	Senior researcher	J02402373E58	30%
Cristina Requejo	Senior researcher	J024074VF3Q	25%
Delfim F. M. Torres	Subproject coordinator	J001957OH25	50%
Eugénio Rocha	Senior researcher	J010723Q271	40%
João Pedro Cruz	Senior Researcher	J0247388G201	30%
Maria Rosália Dinis Rodrigues	Subproject coordinator	J0263245U31	30%
Manuel Guerra	Senior researcher	J02465926JU	30%
Paula Carvalho	Senior Researcher	J024866UV599	40%
Paula Rama	Senior Researcher	J0242726UT3	30%
Rosa Amélia Martins	Senior Researcher	J024086A47G	30%
Tatiana Tchemisova	Senior Researcher	J024049B0ZR	25%
Vitor Neves	Senior Researcher	J02203245U0	30%
Evgeny Lakshatanov	Post-doc	J0225464T0Y	100%
Moulay Rchid Sidi Ammi	Post-doc	J021763HKS	100%
Olena V. Mul	Post-doc	J045337A9HD	100%
António Batel Anjo	Collaborator		
Paula Oliveira	Collaborator		
Ana Mafalda Martins	PhD Student	J00603740R4	100%
António Ferreira Pereira	PhD Student	J02401674V3L	100%
Cristiana J. Silva	PhD student	J003420E03G	100%
Deolinda Maria L. D. Rasteiro	PhD student	J0280770731A	40%
Gastão S. F. Frederico	PhD student	J091910K19A	100%
Inês Pereira de Matos	PhD Student	J0010924RHGP	100%
Natália Martins	PhD Student	J024046TXWTQ	30%
Paulo D. F. Gouveia	PhD student	J010525EG62	100%
Ricardo Almeida	PhD Student	J010525EG62	50%

## Global output indicators of CEOC

Number of Publications	previsto	realizado
Books	1	0
Papers in international journals	17	24
Papers in national journals	1	0
Number of Communications		
in International Meetings	18	46
in National Meetings	4	18
Reports	26	38
Organization of seminars and conferences	29	28
Advanced training		
number of PhD theses	2	3
number of Master theses	5	3
Software		
Computational Applications	0	1

## 1. Optimization, graph theory and combinatorics

### Research team

Name	Member type	Public Key	Percentage
Agostinho Agra	Senior researcher	J024060A9WU	30%
António Batel Anjo	Collaborator		
Carlos J. Luz	Senior researcher	J02402373E58	30%
Cristina Requejo	Senior researcher	J024074VF3Q	25%
Deolinda M.L.D. Rasteiro	PhD student	J0280770731A	40%
Domingos Moreira Cardoso	Coordinator	J02357833N8	40%
Eugénio Rocha	Senior Researcher	J010723Q271	10%
Natália Martins	PhD Student	J024046TXWTQ	30%
Paula Carvalho	Senior Researcher	J024866UV599	40%
Paula Oliveira	Collaborator		
Paula Rama	Senior Researcher	J0242726UT3	30%
Ricardo Almeida	PhD Student	J010525EG62	50%
Rosa Amélia Martins	Senior Researcher	J024086A47G	30%
Tatiana Tchemisova	Senior Researcher	J024049B0ZR	15%
Vitor Neves	Senior Researcher	J02203245U0	30%

### 1.1 Activities during 2006

- During 2006 the last chapters 18-20 of part four of a Portuguese book on discrete mathematics was written, in cooperation with Jerzy Szymanski (from Adam Mickiewicz University, Poznan, Poland) and Mohammad Rostami (from Universidade da Beira Interior). The obtained results about the influence of the presence of  $(k, \tau)$ -regular sets on the existence of par-

ticular adjacency eigenvalues, necessary and sufficient conditions for the existence of  $(k, \tau)$ -regular sets in strongly regular graphs and relations between equitable partitions in a graph and its line graph were accepted for publication in *Linear Algebra and Its Applications* (LAA). The research on graphs with spectral lower bound  $-2$ , whose stability number is determined by convex quadratic programming, developed in co-operation with Dragos Cvetković (University of Belgrade, Serbia), was published in the *Bull. Acad. Serbe Sci. Arts*. The developed work on Delsarte's linear programming bound as a ratio bound on the stability number of a graph was accepted for publication in LAA.

On April 2006, the Aveiro Workshop on Graph Spectra (<http://ceocmat.ua.pt/awgs2006>) brought to the University of Aveiro many researchers among the renowned world specialists on the Theory of Graph Spectra.

Furthermore, we have developed several results in the following topics: New relations between graph parameters and graph eigenvalues, namely new polynomial upper bounds on the clique number and chromatic number of a graph (this study still remains under research). Efficient edge dominating sets as applications of  $(k, \tau)$ -regular sets, in cooperation with J Cerdeira C. Delorme and P. Silva (submitted). Determination of maximum size induced subgraphs developed in co-operation with Marcin Kamiński and Vadim Lozin (RUTCOR - Rutgers University, USA) (submitted). Convex quadratic characterization of the McEliece-Rodemich-Rumsey and Schrijver upper bound on the stability number of a graph (submitted). A mixed integer set which can be seen as substructure of general mixed integer programs were studied. Several polyhedral results were obtained (in particular, a partial polyhedral description of the convex hull of the feasible solutions for the case where the coefficients of the integer variables can assume one of the two possible values). Exact formulations for the special cases of the diameter-constrained version of the classical minimum spanning tree problem, with  $D=2$  or  $3$  were obtained and also some greedy and approximation heuristic methods were developed. New optimality conditions in convex semi-infinite programming were obtained (submitted). Integer programming methods were used for the study of the optimal aerodynamical resistance problem. Results on the study of the second order conditions of the overflow traffic function on Erlang loss systems were obtained and its numerical computations analyzed (submitted). Following *Nonstandard Mathematics 2006*, which took place at the Univ. of Pisa last May, we have been trying to apply our nonstandard formulations of critical point (Palais-Smale type) conditions to differential equations, developing foundations of global analysis of hulls, aiming at applications on the Calculus of Variations too as well as some nonstandard techniques on topology (connectedness), manifold theory and problems of maximum or minimum resistance.

We have finished the two years project (2005-2006) entitled "Algebraic Methods in Graph Theory", supported by Programa PESSOA 2005/GRI-

CES, developed in cooperation with several researchers from Paris-Sud University (C. Delorme, P. Bertholomé, D. Forge, and M. Kouider ) and from Technical University of Lisbon (J. Cerdeira and R. Cordovil). Furthermore, despite the industrial project in cooperation with Yazaki Saltano de Portugal, C.E.A. Lda, entitled "Optimization of Diversity and Distribution of Cable Configuration for Automobile Industry Project" has been developed during 2005, in 2006 this project was selected by a Jury of the Portuguese APDC/Siemens Innovation Prize for the list of the three finalists, the contacts with the company have been continued and several computational experiments with real problems data and improved algorithms were performed (the obtained results were submitted for publication). Additionally, some progress on this problem was performed, in particular the study of dual and primal-dual techniques to provide good lower bounds for the problem.

The study of computational combinatorics, motivated by the open problem of the existence of the fourth Moore graph, is part of a big project on Computational Mathematics, GRID, submitted to FCT, remains under research in co-operation with members of Discrete Mathematics Department of de Adam Mickiewicz University (Poznan, Poland).

During 2006, the following researchers, with joint work with members of OGT&C project, visited our Mathematics Department: Jerzy Szymanski, from Adam Mickiewicz University, Poznan, Poland (July 9-25, 2006).

## 1.2 Output indicators

Number of Publications	previsto	realizado
Books	1	0
Papers in international journals	4	4
Papers in national journals	1	0
<b>Number of Communications</b>		
in International Meetings	6	17
in National Meetings	4	9
Reports	7	14
Organization of seminars and conferences	11	10
<b>Advanced training</b>		
number of PhD theses	2	3
number of Master theses	3	1

## 1.3 List of publications

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

1. A. Agra and Constantino M. F., "Description of 2-integer continuous knapsack polyhedra". *Discrete Optimization*, 3, (2006): 95-110 (accepted in 2005).



2. A. Agra and M. Constantino, "Polyhedral description of the integer single node flow set with constant bounds". *Mathematical Programming*, 105 (2006): 345-364 (accepted with a different title in 2005).
3. D. M. Cardoso and L. A. Vieira, "On the optimal parameter of a self-concordant barrier over a symmetric cone". *European Journal of Operational Research - EJOR*, 169 (2006):1148-1157 (accepted in 2005).
4. G. Dahl, L. Gouveia, C. Requejo, "On formulations and methods for the hop-constrained minimum spanning tree problem". In *Handbook of Optimization in Telecommunications*, edited by M.G.C. Resende and P.M. Pardalos, Springer Science + Business Media, 2006 (accepted in 2005).
5. D. M. Cardoso and D. Cvetkovic, "Graphs with least eigenvalue -2 attaining a convex quadratic upper bound for the stability number". *Bulletin T. CXXXIII de l'Académie des sciences et des arts, Classe des sciences mathématiques et naturelles, sciences mathématiques*, 31 (2006): 41-55.
6. D. M. Cardoso, P. Rama, "Spectral results on graphs with regularity constraints." *Linear Algebra Appl.*, (accepted, doi:10.1016/j.laa.2006.09.028).
7. C. J. Luz, "A characterization of Delsarte's linear programming bound as a ratio bound", *Linear Algebra Appl.* (accepted, doi:10.1016/j.laa.2006.10.009).
8. L. Gouveia, T. Magnanti, C. Requejo, "An intersecting tree model for odd-diameter-constrained minimum spanning and Steiner trees". *Annals of Operations Research*, 146 (2006): 19-39.

## 1.4 List of talks

### • Talks at International Conferences

1. A. Agra and M. Constantino "A polyhedral study of a mixed integer set", ISMP2006, Rio de Janeiro, Brazil, July, 30 to August, 4, 2006.
2. A. Agra and M. Constantino, "Recent results on basic mixed-integer sets", *Mixed Integer and Integer Programming: the way forward - CORE 40th anniversary*, Belgium.
3. C. J. Luz, "A characterization of Delsarte's bound as a ratio bound", *Aveiro Workshop on Graph Spectra*, Aveiro, April 10-12, 2006.
4. C. J. Luz and L. Cavique Santos, "A Heuristic for the Stability Number of a Graph based on Convex Quadratic Programming and Tabu Search", *21st European Conference on Operational Research - EURO XXI*, Reykjavik, July 2-5, 2006.
5. C. J. Luz, Gilberto Catarino, João Campos and Rui Madeira, "b-3mLearning: a blended multimedia system for mathematics learning", *m-ICTE2006*, Sevilha, November 22-25, 2006.

6. D. M. Cardoso and S. Pinheiro, "Continuous optimization polynomial-time upper bounds on the stability number of graphs". Iberian Conference in Optimization, Coimbra, 16-18 November, 2006.
7. D. M. Cardoso, "The class of graphs with convex-qp stability number". International mathematical conference - Topics in mathematical analysis and graph theory (MAGT), Belgrade, August 31 - September 4, 2006.
8. D. M. Cardoso, Convex quadratic programming techniques on graphs, EURO XXI, Reykjavik, July 2-5, 2006.
9. D. M. Cardoso, Paula Rama, Spectral results on graphs with regularity constraints, Aveiro Workshop on Graph Spectra, April 10-12, 2006.
10. Maria Paula Carvalho, Non embeddability in Euclidean 3-space: an algebraic approach, SIGMAC'06, Third Workshop in Symmetries in Graphs, Maps and Complexes, July 17-21, 2006.
11. Natália Martins, Mountain Pass Theorems without Palais-Smale conditions, no encontro internacional Nonstandard Methods and Applications in Mathematics NSM2006, Departamento de Matemática da Universidade de Pisa, Itália, May 25 - 31, 2006.
12. O. Kostyukova, T. Tchemisova. Explicit Optimality Conditions for Convex Semi-Infinite Programming, EURO XXI, Reykjavik, July 2-5, 2006.
13. Ricardo Almeida, Vítor Neves, mu-differentiability of an internal function, NonStandard Methods and Applications in Mathematics", Pisa, Itália, May 25-31, 2006.
14. T. Tchemisova and O. Kostyukova. Convex Parametric Semi-Infinite Programming Problems and Properties of their Solutions in a Neighborhood of Irregular Points, Workshop on Advances in Continuous Optimization, Reykjavik, Iceland, June 30 - July 1, 2006.
15. T. Tchemisova and O. Kostyukova. On new concepts of immobile points and immobility orders in convex semi-infinite programming, EURO XXI, Reykjavik, July 2-5, 2006.
16. T. Tchemisova. Study of a special nonlinear problem arising in convex semi-infinite programming, Iberian Conference in Optimization, Coimbra, 16-18 November, 2006.
17. Vitor Neves. Nonstandard critical point theory, NSM2006, Univ. of Pisa, Italy, May 21-31, 2006.

• **Talks at National Conferences**

1. A. Agra, D. M. Cardoso, J. Cerdeira, M. Miranda and E. Rocha, "Optimização da diversidade e distribuição de cablagens para a indústria automóvel", 12º Congresso da APDIO - IO2006, October 8-11, 2006, Lisboa.

2. C. J. Luz, "Sobre uma abordagem do número de estabilidade de um grafo baseada em técnicas de otimização quadrática", "Tardes de Matemática SPM/CIM", Coimbra, May 6, 2006.
3. C. J. Luz, Aldina Soares and Paulo Ferrão, "Modelação do Funcionamento do Mercado sobre Opções para a Sustentabilidade", 12º Congresso da APDIO - IO2006, Lisbon, October 9-11, 2006.
4. Natália Martins, "Teoremas da Passagem da Montanha sem condições de Palais-Smale". 2th anual meeting of research groups CEOC (Aveiro) and CIMA-UE (Évora), June 12 - 13, 2006.
5. Ricardo Almeida and Vítor Neves, "Perturbações infinitesimais na m-diferenciabilidade". Universidade de Aveiro (SPIMNS), September 23, 2006.
6. Vítor Neves, "Análise não linear em dimensão infinita". Universidade de Aveiro (SPIMNS), September 23, 2006.
7. Ricardo Almeida and Vítor Neves, "Análise Não Standard em Variedades Diferenciáveis". Universidade de Évora (SPIMNS), November 24, 2006.
8. Vítor Neves, "Mónodas e estruturas de convergência". Universidade de Évora (SPIMNS), November 24, 2006.
9. T. Tchemisova, "Implicit optimality criterion for Semi-infinite Programming": 2th anual meeting of research groups CEOC (Aveiro) and CIMA-UE (Évora), June 12 - 13, 2006.

### 1.5 List of reports (including proceedings)

- 1. C. J. Luz, G. Catarino, J. Campos and R. Madeira "b-3mLearning: a blended multimedia system for mathematics learning", "Current Developments in Technology-Assisted Education (2006)", Vol.2, A. Mendez-Villas, A. Solano Martin, J. Mesa González, J. A. Mesa González (Eds.), FORMATEX, Badajoz, Spain, 2006, 1181-1185.
- 2. C. J. Luz, A. Soares, P. Conceição and P. Ferrão, "Modeling Sustainability Options for Recycling Markets", Proceedings of "I International Conference on Sustainability Measurement and Modelling ICSSM 06", E. Carrera, J. J. de Felipe, B. Sureda, N. Tollin (Eds.), CIMNE, Barcelona, 2006.
- 3. C. J. Luz, "A convex quadratic characterization of the McEliece-Rodemich-Rumsey and Schrijver upper bound on the stability number of a graph". Universidade de Aveiro. Cadernos de Matemática CM06/I-14 (2006).
- 4. C. J. Luz, "A characterization of Delsarte's linear programming bound as a ratio bound". Universidade de Aveiro. Cadernos de Matemática CM06/I-15 (2006).

5. D. M. Cardoso, J. O. Cerdeira, C. Delorme, P. C. Silva, "Efficient edge domination in regular graphs."Relatório Técnico 1/06, Unidade Plurianual: Matematica Aplicada - IISA, 2006, 10 p.
6. D. M. Cardoso, "A Matemática e os seus Problemas". Universidade de Aveiro. Cadernos de Matemática CM06/D-2, (2006):17 p.
7. D. M. Cardoso, M. Kaminski and V. Lozin, "Maximum k-regular induced subgraphs". RUTCOR Research Report N.3, March 2006, 11 p.
8. J. S. Esteves, J. Craveirinha, D. M. Cardoso, "Second Order Conditions on the Overflow Traffic from the Erlang-B System."Universidade de Aveiro. Cadernos de Matemática CM06/I-20 (2006): 13 p.
9. O. I. Kostyukova, T. V. Tchemisova, and S. A. Yermalinskaya, "On a Special Nonlinear Problem Arising in the Study of Convex SIP Problems". Universidade de Aveiro. Cadernos de Matemática CM-06/ I-38 (2006).
10. O. I. Kostyukova and T. V. Tchemisova, "Convex Semi-Infinite Programming: Explicit Optimality Conditions". Universidade de Aveiro. Cadernos de Matemática CM 05/I-38, (2006).
11. Ricardo Almeida and Vítor Neves, " $\mu$ -differentiability of an internal function". Universidade de Aveiro. Cadernos de Matemática CM 06/I-18, (2006).
12. Ricardo Almeida, "A nonstandard characterization of regular surfaces". Universidade de Aveiro. Cadernos de Matemática CM 06/I-3, (2006).
13. Ricardo Almeida, "Compact Linear Operators, a survey". Universidade de Aveiro. Cadernos de Matemática CM 06/I-32, (2006).
14. Ricardo Almeida, "On the continuity of functions". Universidade de Aveiro. Cadernos de Matemática CM 06/I-26, (2006).

## 1.6 List of organized seminars and conferences

### • Organized seminars

1. Ana Paías (Universidade de Lisboa ), "Escalonamento integrado de viaturas e tripulações", December 15, 2006.
2. Maria da Conceição Fonseca (Universidade de Lisboa), "Localização de Serviços Semiobnóxios. Alguns Modelos", November 17, 2006.
3. Vitor Neves (Universidade de Aveiro), "Propriedades de diferenciabilidade de Invólucros não Standard Ú I", November 3, 2006.
4. Varporn Saepholphat (Srinahkarinwirot University, Bangkok), "Which graphs are divisor graphs?", October 20, 2006.

5. Farrukh Mukhamedov (National Univ. of Uzbekistan), "On a recursive equation, indexed by a tree, over p-adic numbers", April 28, 2006.
6. André Carlos Ponce de Leon Ferreira de Carvalho (Universidade de São Paulo, Brasil), Técnicas de otimização baseadas na Biologia, April 21, 2006.
7. Tomás Oliveira e Silva (Universidade de Aveiro), "Computações de larga escala em teoria dos números", April 7, 2006.
8. Tatiana Tchemisova (Universidade de Aveiro), "Programação semi-infinita convexa: pontos imóveis e condições de optimalidade", March 10, 2006.

- **Organized conferences**

1. Second Joint Meeting CEOC/CIMA-UE, University of Aveiro June 12 - 13, 2006.
2. Aveiro Workshop On Graph Spectra, University of Aveiro, April 10-12, 2006.

## 1.7 List of PhD and MSc dissertations

- **PhD dissertations**

1. Deolinda Dias Rasteiro, "Network optimization with random parameters", PhD Thesis in Mathematics, University of Aveiro, March 2006 (supervised by António Batel Anjo).
2. Natália Martins, "Some applications of non-standard analysis to critical point theory and differential equations", PhD Thesis in Mathematics, University of Aveiro, April, 2006. (supervised by Vitor Neves and Maria João Borges from Technical University of Lisbon).
3. Jorge Sá Esteves, "Efficiency and equity on the optimization of Erlang-B multidimensional systems", PhD Thesis in Mathematics, University of Aveiro, July 2006 (supervised by José Craveirinha from Coimbra University and Domingos M. Cardoso).

- **MSc dissertations**

1. Rosalina Pinto e Sá, Utilização de uma Plataforma de Ensino Assistido na Primitivação, MSc dissertation in Mathematics, January 2006 (supervised by António Batel Anjo and Paula Oliveira).

## 2. Problems of minimal resistance and problems of mass transfer

### Research team

Name	Member type	Public Key	Percentage
Alexander Plakhov	Subproject coordinator	J019647V383	40%
Delfim Torres	Senior researcher	J001957OH25	10%
Evgeny Lakshatanov	Senior researcher	J0225464T0Y	100%
João Pedro Cruz	Senior Researcher	J0247388G201	30%
Tatiana Tchemisova	Senior Researcher	J024049B0ZR	10%

### 2.1 Activities during 2006

There were several directions of research.

First, there was made a numerical study of some special Monge-Kantorovich problems related to motion of *rotating* bodies and bodies moving in media at *positive absolute temperature*. There was also initiated the study of *multiobjective* Monge-Kantorovich problems. Notice the novelty of this approach: the multiobjective optimization problems have never been studied before in the framework of Monge-Kantorovich optimal mass transfer, however they appear quite naturally in the current study. The obtained results (joint work of Alexander Plakhov and Tatiana Tchemisova) were reported on *12th Congress of APDIO*, hold in Lisbon on Oct. 8 - 11, 2006 and on *Iberian Conf. in Optimization* hold in Coimbra on Nov. 16 - 18, 2006. An article on the subject is now in preparation.

Next, the work on resistance optimization was continued. It was proved by Alexander Plakhov that a wide range of optimal resistance problems in two dimensions can be reduced to one-dimensional Monge-Kantorovich problems. As a by-product, some results from billiard theory were also obtained. An article on the subject is submitted. There was made a numerical and analytical study on resistance *maximization* by Paulo Gouveia and Alexander Plakhov; an article is in preparation; another article is published in *Russ. Math. Surv.* There was started a joint work of Alexander Plakhov and Alena Aleksenko concerning Newton's problem in classes of non-convex axially symmetric bodies.

There was started work concerning the wave (quantum) analogue of the minimal resistance problem (E.L.Lakshtanov, A.I.Aleksenko). In the article *J.Phys.A: Math.Gen.* the notation of the problem was introduced and resistance of the hard sphere for all values of frequencies was found. It was also proved in that article that at high values of frequencies the quantum resistance of the convex hard body tends to the classical one. Later it was proved that for small positive values of frequencies the resistance is less than total cross section. This result is valid for arbitrary hard body; it is the most general result in the quantum scattering theory about scattering by hard obstacles. Significance of this result is the following: in the small frequency limit scattering is isotropic (resistance equals the total cross section), and the direction of anisotropy until

now was unknown to the physical community. We solve this problem basing on the rigorous mathematical methods and calculations.

Further, joint work with the group of Non-standard Analysis was started. The objective is reformulate in the non-standard way the problem and solutions concerning optimal resistance for rough bodies. The advantage of this approach is that the solution always exists and can be explicitly constructed.

In March 2006, Alexander Plakhov made a working visit to Georgia Tech, USA, and gave a talk there.

In May and Sept. 2006, our Mathematics Department and CEOC group was visited by Giuseppe Buttazzo (University of Pisa, Italy).

In May 2006, our Mathematics Department and CEOC group was visited by W.De Roeck (Catholic University of Leuven, Belgium).

## 2.2 Output indicators

Number of Publications	previsto	realizado
Books	0	0
Papers in international journals	3	5
Papers in national journals	0	0
<b>Number of Communications</b>		
in International Meetings	2	2
in National Meetings	0	1
Reports	3	3
Organization of seminars and conferences	4	4
<b>Advanced training</b>		
number of PhD theses	0	0
number of Master theses	0	0

## 2.3 List of publications

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

1. A. Yu. Plakhov, Billiards in unbounded domains reversing the direction of motion of a particle, Russ. Math. Surv. v.61, 2006: 179-180 (accepted in 2005).
2. 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.
3. E. L. Lakshtanov and L. S. Langvagen, Entropy of multidimensional cellular automata, Information Transmission Problems v.42 (1), 2006: 38-45.
4. Cristiana J. Silva and Delfim F. M. Torres, Two-dimensional Newton's Problem of Minimal Resistance, Control & Cybernetics, accepted 06-July-2006 (in press).

5. 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.
6. W. de Roeck, E. L. Lakshtanov, "Total cross section exceeds transport cross section for quantum scattering from hard bodies at low and high wave numbers", *J. Math. Phys.* v.48, 013501 (accepted in November 4, 2006).

## 2.4 List of talks

### • Talks at International Conferences

1. Alexander Plakhov, *Problems of optimal resistance and Monge-Kantorovich mass transport*, Oberwolfach Workshop on Calculus of Variations (Oberwolfach, Germany), July 9 - 16, 2006.
2. Alexander Plakhov and Tatiana Tchemisova, *Optimization problems for Newtonian aerodynamic resistance*, Iberian Conf. in Optimization, Coimbra, Nov. 16 - 18, 2006.

### • Talks at National Conferences

1. Alexander Plakhov, *Billiards in unbounded regions and applications to problems of minimal aerodynamic resistance*, 2nd Meeting *Optimização e Controlo Ótimo*, CEOC (Aveiro) e CIMA-UE (Évora), Aveiro, June 12 - 13, 2006.
2. Alexander Plakhov and Tatiana Tchemisova, *Problemas multiobjetivos de resistência Newtoniana dos corpos não convexos em duas dimensões*, 12th Congress of APDIO, Lisbon, Oct. 8 - 11, 2006.

### • Seminars

1. Alexander Plakhov, *Shapes of minimal aerodynamic resistance*, Georgia Institute of Technology, Atlanta, USA, March 9, 2006.
2. Alexander Plakhov, *Problems of least resistance and billiards: II*, Ya. Sinai seminar, Moscow University, Aug. 10, 2006.
3. Evgeny Lakshtanov, *Quantum analogue of Newton minimal resistance problem*, Ya. Sinai seminar, Moscow University, Aug. 24, 2006.
4. Evgeny Lakshtanov, *Scattering amplitude as a distribution and some applications*, Landau Institute for Theoretical Physics, Moscow, Sept. 8, 2006.
5. Alexander Plakhov, *Newton's problem of least resistance and Monge-Kantorovich problem of mass transportation*, Seminar of the Group of Dynamical Systems (conducted by Acad. D.V. Anosov), Moscow University, Dec. 18, 2006.



## 2.5 List of reports (including proceedings)

- 1. A. Yu. Plakhov, "Billiards and two-dimensional problems of optimal resistance", arXiv:math.OC/0607129v1 5 Jul 2006: 41 p.
- 2. Cristiana J. Silva and Delfim F. M. Torres, "Two-dimensional Newton's Problem of Minimal Resistance", math.OC/0607197 (Date: Fri, 7 Jul 2006). Cadernos de Matemática: Research report CM06/I-01, Dep. Mathematics, Univ. Aveiro, Jan. 2006.
- 3. Alexander Plakhov, "Problemas de Resistência Mínima e Problemas de Transporte de Massa", Cadernos de Matemática, Série: Divulgação CM 06/D-06.

## 2.6 List of organized seminars and conferences

- **Organized seminars**

1. G. Buttazzo (University of Pisa, Italy) "Asymptotic Behavior Of a Compliance-Location Problem", Seminar of CEOC, Universidade de Aveiro, May 17, 2006.
2. W. de Roeck (University of Leuven, Belgium) "The Relation Between Mathematical Entropy and Thermodynamical Entropy", Seminar of CEOC, Universidade de Aveiro, May 30, 2006.
3. M. Shvartsman (University of St. Thomas, USA) "Tornados and Turbulent Kinetic Energy", Seminar of CEOC, Universidade de Aveiro, July 21, 2006.
4. Evgeny Lakshtanov, *Topological entropy of "Game of Life" and similar cellular automata*, Seminar of CEOC, Universidade de Aveiro, March 3, 2006.

## 3. Computability and Algorithms

### Research team

R-; L-; AM-; IPM-

Name	Member type	Public Key	Percentage
Maria Rosália Dinis Rodrigues	Subproject coordinator	J0263245U31	30%
Antonio Leslie Bajuelos Dominguez	Senior researcher	J0010901FT8	30%
Ana Mafalda Martins	PhD Student	J00603740R4	100%
António Ferreira Pereira	PhD Student	J02401674V3L	100%
Inês Pereira de Matos	PhD Student	J0010924RHGP	100%

### 3.1 Activities during 2006

1. **Computational Geometry.**

In cooperation with Antonio L. Bajuelos, Inês Matos has considered the problem of good illumination with minimum range. Due to the lack of reality in most papers related to illumination problems, it is considered that the illumination range of a light is not infinite but is limited, so the illumination range is a parameter to be optimized. This restriction has been applied to *1-good illumination* (also known as *triangle-guarding* or *well covering*). This definition tries to evaluate how well a set of lights surrounds/embraces an object that it is illuminating. If the set of lights is providing a quality illumination to that object (this is, if it is 1-well illuminating it) then the lights' illumination range is optimized while searching for the minimum illumination range, known as the *Minimum Embracing Range* (MER). This problem has already been studied and published for points and polygonal chains by M. Abellanas, G. Hernández (Universidad Politécnica de Madrid), A. Bajuelos and I. Matos (Universidade de Aveiro). However, the published algorithms could be optimized. So in 2006 the previous authors now in cooperation with B. Palop (Universidad de Valladolid) and F. Hurtado (Universitat Politècnica de Catalunya) solved both problems in a more efficient way. The paper *Good Illumination of Minimum Range* computes the MER of a 1-well illuminated point in optimal linear time. In the same paper there is also an algorithm to compute the MER of a 1-well illuminated line segment in quadratic time applying the Parametric Search technique (introduced by N. Megiddo) using parallel computation. This paper was submitted to the *International Journal of Computational Geometry and Applications* in June 2006. All these algorithms have been implemented and tested. It is open whether the problem of computing the MER of a 1-well illuminated set of points is also efficiently solved applying the linear algorithm to each point of the set.

Ana Mafalda Martins and Antonio L. Bajuelos, studied the problem of finding the minimum number of guards placed on vertices needed to cover a given polygon with  $n$  vertices (Minimum Vertex Guard Minimum Vertex (MVG) Problem), which is a NP-hard problem both for arbitrary and orthogonal polygons. In particular, they considered this problem for a subclass of orthogonal polygons, the grid  $n$ -ogons. With the aim of simplifying the study of this problem, they also characterized some structural properties of this subclass of orthogonal polygons. Ana Mafalda Martins also started investigating how to develop and implement algorithms to compute approximate solutions of some NP-hard visibility problems, namely, heuristics and meta-heuristics for the MVG problem in orthogonal polygons and for the Maximum Hidden Set (MHS) and Maximum Hidden Vertex Set (MHVS) problems in orthogonal polygons using CGAL (Computational Geometry Algorithm Library) system.

Ana Gonçalves and Antonio L. Bajuelos in cooperation with Ana Paula Tomás (Departamento de Ciências da Computação, Faculdade de Ciências, Universidade de Porto) worked in the improvement of an approxima-

tion algorithm (proposed by Tomas, Bajuelos and Marques) for the MVG problem for orthogonal polygons. To obtain each approximation it solves a minimum set covering problem, associated to a partition of the polygon. A Constraint Programming approach is used to solve this problem.

During 2006, Ana Mafalda Martins and Inês Matos participated in the advanced course entitled "Combinatorial and Computational Geometry: Trends and Topics for the Future", August 31 to September 5, 2006, Alcalá de Henares, Spain (this course was a satellite activity of the I.C.M. Madrid 2006).

Several informal working meetings took place during 2006. In April, Inês Matos visited (for two months and supported by the Calouste Gulbenkian grant) the Facultad de Matemática Aplicada of the Universidad Politécnica de Madrid to work with Manuel Abellanas. In August, I. Matos went to Madrid (supported by the "Projecto de Acções Integradas Luso-Espanholas" grant) to work with J. Mitchell (State University of New York at Stony Brook), P. Ramos (Universidad de Alcalá) and M. Abellanas. The following researchers, with joint research interests with the members of our sub-group, visited the Department of Mathematics of the University of Aveiro during 2006: Manuel Abellanas, Facultad de Matemática Aplicada, Universidad Politécnica de Madrid, February 5-8, 2006, Gregorio Hernandez, Facultad de Matemática Aplicada, Universidad Politécnica de Madrid, February 5-8, 2006 and September 25-27, 2006, Santiago Canales, Universidad Pontificia de Comillas, Madrid, September 25-27, 2006.

All member of our sub-group have participated in the following project: "Problems of Illumination and Visibility in Computational Geometry", Acções Integradas Luso-Espanholas, 2006-2007, No. E-77/06.

## 2. Quantum Computation.

Two main topics have been analyzed in 2006: *Quantum Arithmetic Algorithms and Complexity* and *Quantum Computation Simulation*.

- The effect of merging the concepts of *Redundant Number Systems* and *Quantum Computation* has been studied, mainly towards the building of Quantum Arithmetic Algorithms.

Several favorable opinions have been advanced on the feasibility of Quantum Computation models where the unit of information, the *qudit*, has more than the two levels provided by the *qubit*. However, the equivalence between this model and the *qubit* based one is only partially established.

The Computational Complexity analysis of *Hybrid Quantum Computation* models where mixtures of several, distinct, units of information coexist has just started. We have considered a new and general formal model for Quantum Computation with Hybrid Quantum Systems, generalizing, by inclusion, all the above mentioned models.

Based on this model, we have built two classes of constant depth quantum circuits for the addition of two numbers in redundant number systems.

Also, we have derived conditions for the feasibility of addition, in constant time, of a polynomial number of numbers (represented in any redundant number system) and justified the existence of constant depth quantum circuits for approximating the sum of a polynomial number of numbers.

- A general purpose *Symbolic Quantum Computation Simulator* (SQCS) has also being developed. SQCS is a *Mathematica* package for the simulation of quantum algorithms. It has been tested on most of the well-known quantum algorithms, such as Grover's database search, but can also be a useful tool in the teaching and learning of the basics of quantum computation.

Existing quantum computer simulators only handle limited magnitude problems (e.g., simulation of quantum circuits with up to 30 qubits). The design and principles presented in SQCS allow for problem instances that are only limited by the amount of entanglement taking place during the simulation of an algorithm, not by the size of the underlying Hilbert space.

This results of this work have been presented at the ICCS06 (International Conference on Computer Science 2006, Reading, UK) and published in the Lecture Notes in Computer Science - 3992.

In 2006 António Pereira has submitted his PhD thesis on "*Algorithms and Complexity in the Quantum Computation Model*" and Sérgio Fernandes has started his PhD project in the topic of "*Quantum Computation Simulators*".

### 3.2 Output indicators

<b>Number of Publications</b>	<b>previsto</b>	<b>realizado</b>
Books	0	0
Papers in international journals	4	4
Papers in national journals	0	0
<b>Number of Communications</b>		
in International Meetings	3	4
in National Meetings	0	2
Reports	2	2
Organization of seminars and conferences	5	5
<b>Advanced training</b>		
number of PhD theses	0	0
number of Master theses	0	0

### 3.3 List of publications

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

1. Mafalda A.M, Bajuelos A. L.: "Characterizing and Covering Some Subclasses of Orthogonal Polygons", Computational Science - ICCS 2006, Lecture Notes in Computer Science (LNCS) 3992, Springer-Verlag, (2006), Chapter: pp 255-262.
2. Martins A. M., Bajuelos A, L.: "Guarding two Subclasses of Orthogonal Polygons", Recent Progress in Computational Sciences and Engineering, Lecture Series on Computer and Computational Sciences (LSCCS), Volume 7, VSP/Brill, (2006), Chapter: pp 372-375.
3. Martins A. M., Bajuelos A, L.: "Vertex Guards in a Subclass of Orthogonal Polygons", International Journal of Computer Science & Network Security (IJCSNS), Vol. 6, No. 9, September 2006, pp 102-108.
4. Pereira A., Rodrigues, R., "A Symbolic Approach to Quantum Computation Simulation", Lecture Notes on Computer Science 3992, V.N. Alexandrov et al. (Eds.), Springer-Verlag Berlin Heidelberg, 2006.

### 3.4 List of talks

- **Talks at International Conferences**

1. A. L. Bajuelos, On Visibility Problems in the Plane - Solving Minimum Vertex Guard Problems by Successive Approximations", "Ninth International Symposium on Artificial Intelligence and Mathematics, Fort Lauderdale, Florida, USA, January, 2006.
2. A. L. Bajuelos, Guarding two Subclasses of Orthogonal Polygons, International Conference of Computational Methods in Sciences and Engineering (ICCMSE 2006), Chania, Crete, Greece, October, 2006.
3. A. M. Martins, Characterizing and Covering some Classes of Orthogonal polygons, International Conference on Computer Science 2006 (ICCS 2006), Reading, UK, May, 2006.
4. A. Pereira and R. Rodrigues, "A Symbolic Approach to Quantum Computation Simulation", ICCS06- International Conference on Computer Science 2006 (ICCS 2006), Reading, UK, May 28-31, 2006.

- **Talks at National Conferences**

1. A. M. Martins, Caracterização e Vigilância de algumas Subclasses de Polígonos Ortogonais, Encontro CEOC-UA e CIMA-UE, 12 e 13 de Junho de 2006, Departamento de Matemática, Universidade de Aveiro (2006).

2. A. Pereira A. and R. Rodrigues, "Um ponto de vista de vista simbólico sobre a Simulação de Algoritmos Quânticos", Encontro CEOC-UA e CIMA-UE, Departamento de Matemática, Universidade de Aveiro, 12 e 13 de Junho de 2006.

### 3.5 List of reports (including proceedings)

1. Tomás A. P., Bajuelos A. L., Marques F.: "On Visibility Problems in the Plane - Solving Minimum Vertex Guard Problems by Successive Approximations", in on-line Proceedings of Artificial Intelligence and Mathematics, Florida, USA, <http://anytime.cs.umass.edu/aimath06/>, (2006).
2. Pereira A., Rodrigues, R., "On the Symbolic Simulation of Quantum Computation with Mathematica", Conference Proceedings from the 5-th International Conference Aplimat 2006, ISBN 80-967305-4-1, 635-642, 2006.

### 3.6 List of organized seminars and conferences

- **Organized seminars**

1. A. M. Martins, O Problema Minimum Vertex Guard (MVG) em grid n-ogons, Seminar of CEOC, Universidade de Aveiro, November 24, 2006.
2. I. Matos, "Diagrama de Voronoi Envolvente", Seminar of CEOC, Universidade de Aveiro, November 10, 2006.
3. M. Teresa F. Oliveira-Martins, Departamento de Matemática da Universidade de Coimbra, "Uma Conexão de Galois", Seminar of CEOC, Universidade de Aveiro, May 19, 2006.
4. Ana Maria Carvalho de Almeida, Departamento de Matemática da Universidade de Coimbra, "Um problema complicado envolvendo árvores de custo mínimo", Seminar of CEOC, Universidade de Aveiro, February 10, 2006.
5. A. Pereira, "Sobre a Complexidade de Circuitos no Modelo Quântico de Computação", Seminar of CEOC, Universidade de Aveiro, February 3, 2006.

## 4. Control Theory Group

### Research team

Name	Member type	Public Key	Percentage
Delfim F. M. Torres	Subproject coordinator	J001957OH25	40%
Cristiana J. Silva	PhD student	J003420E03G	100%
Eugénio Rocha	Senior researcher	J010723Q271	30%
Gastão S. F. Frederico	PhD student	J091910K19A	100%
Manuel Guerra	Senior researcher	J02465926JU	30%
Moulay Rchid Sidi Ammi	Post-doc	J021763HKS	100%
Olena V. Mul	Post-doc	J045337A9HD	100%
Paulo D. F. Gouveia	PhD student	J010525EG62	100%

### 4.1 Activities done during 2006

Manuel Guerra has considered the problem of minimizing a quadratic noncoercive functional along the trajectories of a control-affine system. Due to lack of coercivity, existence of "classical" minimizers cannot, in general, be guaranteed. Under appropriate commutativity assumptions the problem can be extended into the space of generalized controls of class  $W_{-1,\infty}$  and reduced into a new problem which is generically coercive but nonconvex. It was shown how to extend further the problem in order to include generalized controls which are "generalized derivatives of one-parameter families of regular probability measures", thus achieving convexification. Generalized trajectories for this type of controls exist only in a weak sense. A geometric formulation of Pontryagin maximum principle for the extended problem was given. This gives a geometric characterization of the limit trajectories approximated by minimizing sequences of the original problem.

An open problem has been suggested by Yu. Orlov for a recently published volume "Unsolved Problems in Mathematical Systems and Control Theory", V.D. Blondel & A. Megretski (eds), Princeton Univ. Press, 2004. The problem regards possible approaches to regularization of control-affine optimal control problems which may admit 'cheap (generalized) controls' as minimizers. It was shown by M. Guerra and A. Sarychev that Orlov's conjecture admits, in general, a positive answer, independently of commutativity assumptions for the controlled fields and other issues typically involved in the study of generalized controls. An index to measure the "singular behavior" of minimizing sequences for control-affine optimal control problems was proposed. It is shown that, in the particular case of singular linear-quadratic problems, this index is tightly related to the "order of singularity" of the problem. A partial result for the commutative nonlinear case was obtained. Some new open problems were posed.

In cooperation with Maria de Lourdes Centeno (Universidade Técnica de Lisboa/ISEG), M. Guerra studied the optimal form of reinsurance from the ceding company point of view, when the cedent seeks to maximize the adjustment coefficient of the retained risk. The problem was studied by exploring the re-

relationship between maximizing the adjustment coefficient and maximizing the expected utility of wealth for the exponential utility function, both with respect to the retained risk of the insurer. Assuming that the premium calculation principle is a convex functional and that some other quite general conditions are fulfilled, existence and uniqueness of solutions was proved, together with a necessary optimality condition. These results are used to find the optimal reinsurance policy when the reinsurance premium calculation principle is the expected value principle or the reinsurance loading is an increasing function of the variance. In the expected value case the optimal form of reinsurance is a stop loss contract. In the other cases, it is described by a nonlinear function.

Eugénio A. M. Rocha was Chairman of the Organizing Committee of the International Conference "Communicating Mathematics in the Digital Era" that took place in Aveiro, 15-18 August 2006, and which was a satellite conference of the International Congress of Mathematicians 2006. In this conference Eugénio presented a mathematical model that describes the publication process in Mathematics, defining an appropriate topology in the space of authors and publications.

In cooperation with Delfim F. M. Torres, a method to compute effective first integrals by combining Noether's principle with the Kozlov-Kolesnikov integrability theorem was obtained. A sufficient condition for the integrability by quadratures of optimal control problems with controls taking values on open sets was proved. We illustrated our approach on some problems taken from the literature. An alternative proof of the integrability of the sub-Riemannian nilpotent Lie group of type (2,3,5) was also given.

Paulo D. F. Gouveia, Delfim F. M. Torres and Eugénio A. M. Rocha used a computer algebra system to compute, in an efficient way, optimal control variational symmetries up to a gauge term. The symmetries were then used to obtain families of Noether's first integrals, possibly in the presence of nonconservative external forces. As an application, we obtained eight independent first integrals for the sub-Riemannian nilpotent problem (2,3,5,8).

Gastão S. F. Frederico and Delfim F. M. Torres extended 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 were derived.

Fractional (or non-integer) differentiation is an important concept both from theoretical and applicational points of view. The study of problems of the calculus of variations with fractional derivatives is a rather recent subject, the main result being the fractional necessary optimality condition of Euler-Lagrange obtained in 2002. The notion of Euler-Lagrange fractional extremal was used to prove a Noether-type theorem. For that a generalization of the classical concept of conservation law was proposed, by introducing an appropriate fractional operator. It was then obtained, following the Lagrange multiplier technique, a new version of Noether's theorem to fractional optimal control systems.



A Noether symmetry theorem to fractional action-like Riemann-Liouville variational functionals was also proved.

Moulay Rchid Sidi Ammi and Delfim F. M. Torres used a dual mesh numerical method to study a non-local parabolic problem arising from the thermistor problem. The thermistor problem and its variants have applications in several fields of physics and in industry.

A system of nonlinear partial differential equations resulting from the traditional modelling of oil engineering within the framework of the mechanics of a continuous medium was studied. Existence and regularity of the optimal solutions for this system were established, together with appropriate necessary optimality conditions.

Delfim F. M. Torres addressed with Agnieszka B. Malinowska, from the Institute of Mathematics & Physics of Bialystok Technology University, the problem of obtaining well-defined criteria for multiobjective optimal control systems. Necessary and sufficient conditions for an optimal control functional to be nonessential were proved. The results provide effective tools for determining nonessential objectives in vector-valued optimal control problems.

Optimal control problems are usually addressed with the help of the famous Pontryagin Maximum Principle (PMP) which gives a generalization of the classical Euler-Lagrange and Weierstrass necessary optimality conditions of the calculus of variations. Success in applying the PMP permits to obtain candidates for a local minimum. In 1967 a direct method, which permits to obtain global minimizers directly, without using necessary conditions, was introduced by Leitmann. Leitmann's approach is connected, as showed by Carlson in 2002, with "Caratheodory's royal road of the Calculus of variations". Cristiana J. Silva and Delfim F. M. Torres proposed a related but different direct approach to problems of the calculus of variations and optimal control, which permit to obtain global minima directly, without recourse to needle variations and necessary conditions. The new method was inspired by the classical Noether's theorem and its recent extensions to optimal control. We have used the variational symmetries of the problem, considering parameter-invariance transformations and substituting the original problem by a parameter-family of optimal control problems. Parameters are then fixed in order to make the problem trivial, in some sense. Finally, by applying the inverse of the chosen invariance-transformation, we get the global minimizer for the original problem. The proposed method was illustrated, by solving concrete problems, and compared with Leitmann's approach.

Olena V. Mul has studied possible vibrations in a nonlinear dynamical system of controlled machine units with discrete parameters described by a system of ordinary differential equations of the fifth order with nonlinear boundary conditions. Ways to decrease the harmful effect of vibrations on normal functioning of the considered control system were obtained. For the investigations the averaging method was applied, which allowed to determine conditions of stability of both one-frequency stationary modes and biharmonic ones. Amplitudes of

the vibrations, as well as the character of transient to the stationary modes, were obtained. Dependence of stationary modes on the different parameters of the system were analyzed.

In cooperation with Delfim F. M. Torres, Olena V. Mul studied the possibilities of using the method of normal fundamental systems for solving some problems of oscillation theory. Large elastic dynamical systems with continuous and discrete parameters were considered, which have many different engineering applications. Intensive oscillations in such systems are possible, but not desirable. Therefore, it is very important to obtain conditions for which oscillations take or not-take place. Mathematically, one needs to search for the solutions of partial differential equations satisfying both boundary and conjugation conditions. The obtained results permit to analyze the influence of different system parameters on oscillations as well as to compute the optimal feedback parameters for the active vibration control of the systems. Dynamics of the hybrid systems of aerial cable-ways were investigated. The eigenvalue problems were considered for such hybrid systems with different assumptions.

Several informal working meetings took place during 2006. The following researchers, with joint research interests with members of the *cotg*, visited the Department of Mathematics of the University of Aveiro during 2006: Inta Volodko, Department of Engineering Mathematics, Riga Technical University, Latvia, February 15-24, 2006; Agnieszka B. Malinowska, Institute of Mathematics & Physics, Bialystok Technology University, Bialystok, Poland, June 5-12, 2006; Andrey V. Sarychev, Università degli Studi di Firenze, Italy, October 25 to November 1, 2006; Ilona Dzenite, Department of Engineering Mathematics, Riga Technical University, Latvia, November 26 to December 06.

## 4.2 Output indicators

<b>Number of Publications</b>	<b>previsto</b>	<b>realizado</b>
Books	0	0
Papers in international journals	6	11
Papers in national journals	0	0
<b>Number of Communications</b>		
in International Meetings	7	23
in National Meetings	0	6
Reports (including proceedings)	12	19
Organization of seminars and conferences	9	9
<b>Advanced training</b>		
number of PhD theses	0	0
number of Master theses	2	2
<b>Software</b>		
Computational Applications	0	1

### 4.3 List of publications

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

1. Gela Chikadze, Nino Mchedlishvili, Valida Sesadze and Delfim F. M. Torres, Structural Stability of Nonlinear Dynamic Control Systems, Scientific Proceedings of Riga Technical University, 48th international thematic issue: Boundary Field Problems and Computer Simulation, series Computer Science, 2006 (in press).
2. Ilona A. Dzenite, Delfim F. M. Torres, A Remark on Noether's Theorem of Optimal Control, *Int. J. Appl. Math. Stat.*, Vol. 4, No. J06, 2006, pp. 88-93.
3. Abderrahmane El Hachimi, Moulay Rchid Sidi Ammi, Delfim F. M. Torres, A dual mesh method for a non-local thermistor problem, *SIGMA Symmetry Integrability Geom. Methods Appl.* 2 (2006), Paper 058, 10 pp. (electronic); [Zbl: 1092.35512] [MR: 2240731]
4. R. A. El-Nabulsi, I. A. Dzenite, and Delfim F. M. Torres. Fractional action functional in classical and quantum field theory, Scientific Proceedings of Riga Technical University, 48th international thematic issue: Boundary Field Problems and Computer Simulation, series Computer Science, 2006 (in press).
5. Gastão S. F. Frederico, Delfim F. M. Torres. Constants of motion for fractional action-like variational problems, *Int. J. of Applied Mathematics*, Vol. 19, No. 1 2006, pp. 97-104. [MR: 2256417]
6. Paulo D. F. Gouveia, Delfim F. M. Torres and Eugénio A. M. Rocha, Symbolic Computation of Variational Symmetries in Optimal Control, *Control & Cybernetics*, Vol. 35 (2006) No. 4 (in press).
7. Olena V. Mul, Analysis of Vibrations in Discrete Parameter Machine Units, *International Journal of Applied Mathematics & Statistics*, Vol. 6, No. D06, December 2006, pp. 56-69.
8. Eugénio A. M. Rocha and Delfim F. M. Torres, Quadratures of Pontryagin Extremals for Optimal Control Problems, *Control & Cybernetics*, Vol. 35 (2006) No. 4 (in press).
9. Rui C. Rodrigues and Delfim F. M. Torres, Generalized splines in  $\mathbb{R}^n$  and optimal control. *Rend. Sem. Mat. Univ. Pol. Torino*, Vol. 64 (2006) No.1, pp. 63-78. [MR: 2201074]
10. Cristiana J. Silva, Delfim F. M. Torres. Absolute Extrema of Invariant Optimal Control Problems, *Commun. Appl. Anal.* Vol. 10, No. 4, 2006 (in press).
11. Delfim F. M. Torres, A Noether Theorem on Unimprovable Conservation Laws for Vector-Valued Optimization Problems in Control Theory. *Georgian Mathematical Journal*, Vol. 13 (2006), No 1, pp. 173-182. [Zbl: 05056603] [MR: 2242336]

#### 4.4 List of talks

- **Talks at International Conferences**

1. M. Lourdes Centeno and M. Guerra, The optimal reinsurance policy in terms of the adjustment coefficient criterion, 10th International Congress on Insurance: Mathematics and Economics, Lovaina, Bélgica, 18-20 de Julho, 2006.
2. Pedro A. F. Cruz and Delfim F. M. Torres, Evolution Strategies on Optimal Control – a numerical study, 5th Junior European Meeting on Control and Information Technology (JEM'06), Tallinn, Estonia, September 20-22, 2006 .
3. Paulo D. F. Gouveia, Delfim F. M. Torres, A Maple interface for computing variational symmetries in optimal control, poster presented by Paulo D. F. Gouveia at ICM 2006: International Congress of Mathematicians, Madrid, Spain, August 22-30, 2006.
4. M. Guerra, Generalized Synthesis for Singular Nonlinear Optimal Control Problems. International Symposium on Generalized Solutions in Control Problems. Ulan Ude, Russia, July 4-7, 2006.
5. M. Guerra and A. Sarychev, Approximation of generalized minimizers and regularization of optimal control problems. 3rd Workshop on Lagrangian and Hamiltonian Methods for Nonlinear Control (LHMNLC'06), Nagoya, Japan, July 19-21, 2006.
6. M. Guerra and A. Sarychev, Regularizations of optimal control problems for control-affine systems. 17th International Symposium on Mathematical Theory of Networks and Systems (MTNS 2006), Kyoto, Japan, July 24-28, 2006.
7. Agnieszka B. Malinowska and Delfim F. M. Torres, Nonessential Functionals in Multiobjective Optimal Control Problems, 5th Junior European Meeting on Control and Information Technology (JEM'06), Tallinn, Estonia, September 20-22, 2006 .
8. Olena Mul, "Analysis of Some Hybrid Controlled Systems", INTAS Summer School on Nonlinear Analysis with Applications in Economics, Energy, and Transportation, Bergamo, Italy, June 5-9, 2006.
9. Olena Mul, "Some Applications of Partial Differential Equations For Analysis And Control of Hybrid Oscillation Systems"(poster), A Conference in Honor of Thomas I. Seidman "Advances in Control of Partial Differential Equations", Department of Mathematics and Statistics, University of Maryland, Baltimore County, USA, October 28 - 29, 2006.
10. Olena V. Mul and Delfim F. M. Torres, Dynamics of Controlled Hybrid Systems of Aerial Cable-Ways, The International Conference of Hybrid Systems and Applications, The University of Louisiana, Lafayette, LA, USA, May 22-26, 2006 .

11. Moulay Rchid Sidi Ammi, "Error estimates to a nonlocal parabolic problem" at ICM 2006: International Congress of Mathematicians, Madrid, Spain, August 22-30, 2006.
12. Moulay Rchid Sidi Ammi and Delfim F. M. Torres, Regularity of Minimizers in the second-Order Calculus of Variations, 2nd Podlasie Conference of Mathematics (Druga Podlaska Konferencja Matematyczna), University of Mathematics and Applied Computer Science, Bialystok, Poland, April 2006.
13. Moulay Rchid Sidi Ammi and Delfim F. M. Torres, Existence and uniqueness of solutions for a nonlocal parabolic thermistor-type problem, 13th IFAC Workshop on Control Applications of Optimisation, CAO'06, Paris - Cachan, France, 26-28 April 2006.
14. Moulay Rchid Sidi Ammi and Delfim F. M. Torres, "Regularity of Minimizers in the second-Order Calculus of Variations", Conference "Views on ODEs" June 21-24, 2006 in honour of the Professors Arrigo Cellina and James A. Yorke on the occasion of their 65th birthday, Aveiro, Portugal.
15. Moulay Rchid Sidi Ammi and Delfim F. M. Torres, A Dead oil isotherm optimal control problem (poster), A Conference in Honor of Thomas I. Seidman "Advances in Control of Partial Differential Equations", Department of Mathematics and Statistics, University of Maryland, Baltimore Country, USA, October 28 - 29, 2006.
16. Cristiana J. Silva and Delfim F. M. Torres, A new direct optimization method for problems of the calculus of variations and optimal control, Trends and Challenges in the Calculus of Variations and its Applications, Convento de Madre de Dios, Toledo, Spain, ICM Satellite Conference, August 16-19, 2006 .
17. Delfim F. M. Torres and Gastão S. F. Frederico, The Noether's Principle and Fractional Differentiation, 2nd Podlasie Conference of Mathematics (Druga Podlaska Konferencja Matematyczna) (invited talk), University of Mathematics and Applied Computer Science, Bialystok, Poland, April 2006.
18. Delfim F. M. Torres and Gastão S. F. Frederico, Nonconservative Noether's Theorem in Optimal Control, 13th IFAC Workshop on Control Applications of Optimisation (CAO'06), Paris - Cachan, France, April, 2006.
19. Delfim F. M. Torres and Gastão S. F. Frederico, Noether's theorem for fractional optimal control problems, Fractional Differentiation and its Applications (FDA'06), 19 - 21 July, 2006, Porto, Portugal .
20. Delfim F. M. Torres and Olena V. Mul, Some Applications of the Method of Normal Fundamental Functions to Oscillation Problems, MTNS 2006 – the 17th International Symposium on Mathematical Theory of Networks and Systems, July 24-28, 2006, Kyoto, Japan.

21. Delfim F. M. Torres and Moulay Rchid Sidi Ammi, Lipschitzian Regularity of Minimizers in the Higher-Order Calculus of Variations, 5th Junior European Meeting on Control and Information Technology (JEM'06), September 20-22, 2006, Tallinn, Estonia .
22. Delfim F. M. Torres and Cristiana Silva, Absolute Extrema of Invariant Optimal Control Problems, Third International Conference of Applied Mathematics, August 12-18, 2006, Plovdiv, Bulgaria.
23. Delfim F. M. Torres and Cristiana Silva, Direct Optimization of Invariant Optimal Control Problems, 5th Junior European Meeting on Control and Information Technology (JEM'06), September 20-22, 2006, Tallinn, Estonia .

• **Talks at National Meetings**

1. M. Guerra, Geometrical synthesis for noncoercive nonconvex optimal control problems. Proceedings of CONTROLO'2006, 7th Portuguese Conference on Automatic Control, IST 11-13 September 2006.
2. M. Guerra and Maria de Lourdes Centeno, Contratos de resseguro óptimos para uma seguradora que procura minimizar o risco de ruína, Encontro CEOC-UA e CIMA-UE, 12 e 13 de Junho de 2006, Departamento de Matemática, Universidade de Aveiro.
3. Olena V. Mul, Delfim F. M. Torres and Volodymyr P. Kravchenko, Problemas de valores próprios para alguns sistemas híbridos de controlo de teleféricos, Encontro CEOC-UA e CIMA-UE, 12 e 13 de Junho de 2006, Departamento de Matemática, Universidade de Aveiro.
4. Moulay Rchid Sidi Ammi, "Error estimates to a nonlocal parabolic problem", "Control, Optimization and Computation", CONTROLO 2006 - 7th Portuguese Conference on Automatic Control, Lisbon, 11-13 September 2006.
5. Moulay Rchid Sidi Ammi and Delfim F. M. Torres, Regularity of solutions to variational problems with higher order derivatives, Encontro CEOC-UA e CIMA-UE, 12 e 13 de Junho de 2006, Departamento de Matemática, Universidade de Aveiro.
6. Delfim F. M. Torres and Moulay Rchid Sidi Ammi, Regularity of solutions to second-order integral functionals in variational calculus, Invited Session "Control, Optimization and Computation", CONTROLO 2006 - 7th Portuguese Conference on Automatic Control, Lisbon, 11-13 September 2006.

#### 4.5 List of reports (including proceedings)

1. Pedro A. F. Cruz, Delfim F. M. Torres. Evolution Strategies on Optimal Control, Proc. 5th Junior European Meeting on Control & Information Technology (JEM'06), September 20-22, 2006, Tallinn, Estonia. Also available as Report no. CM06;I-44.

2. Abderrahmane El Hachimi, Moulay Rhid 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.
3. Gastão S. F. Frederico and Delfim F. M. Torres, Nonconservative Noether's Theorem in Optimal Control, Proc. 13th IFAC Workshop on Control Applications of Optimisation (CAO'06), 26-28 April 2006, ENS de Cachan, Paris, pp. 127-132.
4. Gastão S. F. Frederico, 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. Also available as Reports math.OC/0603598 and CM06/I-11.
5. Gastão S. F. Frederico, Delfim F. M. Torres, A Formulation of Noether's Theorem for Fractional Problems of the Calculus of Variations. Accepted to J. Math. Anal. Appl. (2007). Available as Reports math.OC/0701187 and CM06/I-04.
6. M. Guerra, Generalized Synthesis for Singular Nonlinear Optimal Control Problems. Proceedings of the International Symposium on Generalized Solutions in Control Problems. Ulan Ude, Russia, July 4-7, 2006.
7. M. Guerra, Geometrical synthesis for noncoercive nonconvex optimal control problems. Proceedings of CONTROLO'2006, 7th Portuguese Conference on Automatic Control, IST 11-13 September 2006.
8. M. Guerra and M.L. Centeno, Optimal reinsurance policy: the adjustment coefficient and the expected utility criteria. Submitted to the special issue of the journal "Insurance: Mathematics and Economics", devoted to the 10th IME Congress, 2006. Available as Report CEMAPRE *N*<sup>o</sup> 1/2006.
9. M. Guerra and A. Sarychev, Approximation of generalized minimizers and regularization of optimal control problems. Proceedings of the 3rd Workshop on Lagrangian and Hamiltonian Methods for Nonlinear Control (LHMNLC'06), Nagoya, Japan, July 19-21, 2006.
10. M. Guerra and A. Sarychev, Regularizations of optimal control problems for control-affine systems. Proceedings of the 17th International Symposium on Mathematical Theory of Networks and Systems (MTNS 2006), Kyoto, Japan, July 24-28, 2006.
11. Agnieszka B. Malinowska, Delfim F. M. Torres. Nonessential Functionals in Multiobjective Optimal Control Problems, Proc. 5th Junior European Meeting on Control & Information Technology (JEM'06), September 20-22, 2006, Tallinn, Estonia. Also available as Reports math.OC/0609731 and CM06/I-33.

12. Olena V. Mul, Delfim F. M. Torres. Some Applications of the Method of Normal Fundamental Functions to Oscillation Problems, Proceedings of MTNS 2006 (the 17th International Symposium on Mathematical Theory of Networks and Systems), Kyoto, Japan, July 24-28, 2006, pp. 2078–2082. Also available as Reports math.NA/0607203 and CM06/I-17.
13. Olena V. Mul, Delfim F. M. Torres and Volodymyr P. Kravchenko, Dynamics of Controlled Hybrid Systems of Aerial Cable-Ways. Accepted to Nonlinear Analysis: Hybrid Systems, Vol. 1 (2007). Available as Reports CM06;I-16 and math.NA/0607200.
14. Frederico D. Regateiro and Delfim F. M. Torres, Extremais do Cálculo das Variações em Maple, Report CM06/D03.
15. Moulay Rchid Sidi Ammi, "Error estimates to a nonlocal parabolic problem", "Control, Optimization and Computation", Proceedings of the 7th Portuguese Conference on Automatic Control – CONTROLO 2006, Instituto Superior Técnico, Lisboa, Portugal, September 11-13, 2006 (electronic).
16. Moulay Rchid Sidi Ammi and Delfim F. M. Torres. Regularity of solutions to second-order integral functionals in variational calculus, Proceedings of the 7th Portuguese Conference on Automatic Control – CONTROLO 2006, Instituto Superior Técnico, Lisboa, Portugal, September 11-13, 2006 (6 pages, electronic). Also available as Report no. CM06/I-21.
17. Moulay Rchid Sidi Ammi and Delfim F. M. Torres, Existence and Regularity of Optimal Solution for a Dead Oil Isotherm Problem. Accepted for publication in the journal "Differential Geometry – Dynamical Systems"(22-July-2006). To appear in 2007. Available as Reports math.OC/0608378 and CM06/I-27.
18. Moulay Rchid Sidi Ammi and Delfim F. M. Torres, Necessary Optimality Conditions for a Dead Oil Isotherm Optimal Control Problem. Accepted to Journal of Optimization Theory and Applications (JOTA). To appear in Vol. 134, No. 2, 2007 (in press). Available as Reports CM06;I-42 and math.OC/0612376.
19. Moulay Rchid Sidi Ammi and Delfim F. M. Torres, Numerical analysis for a nonlocal parabolic problem resulting from thermistor problem, Report CM06/I-25.

## 4.6 List of organized seminars and conferences

- **Organized seminars**

1. Inta Volodko, Unsteady flows of a viscous incompressible fluid, Department of Engineering Mathematics, Riga Technical University, Riga LV-1658, Latvia. Seminar of CEOC, February 17, 2006.



2. Ilona A. Dzenite, On the Formula for Impedance Change Used in Problems of Non-Destructive Testing by Eddy Current Method, Department of Engineering Mathematics, Riga Technical University, Latvia. Seminar of CEOC, February 24, 2006.
3. Gastão S. F. Frederico, Teorema de Noether no Cálculo das Variações Fraccionário, Bolseiro do IPAD. Seminar of CEOC, March 17, 2006.
4. Moulay Rachid Sidi Ammi, A Chernoff scheme to approximate a non-local parabolic problem, Post-Doc, Universidade de Aveiro. Seminar of CEOC, March 24, 2006.
5. Olena Mul, Eigenvalue Problems For Some Hybrid Aerial Cable-Way Systems, Post-Doc Universidade de Aveiro. Seminar of CEOC, March 31, 2006.
6. Agnieszka B. Malinowska, Nonessential Objective Functions in Vector Optimization Problems, Technical University of Bialystok, Poland. Seminar of CEOC, June 8, 2006.
7. Andrey Sarychev, Controlabilidade para algumas equações não lineares de física matemática, Università degli Studi de Firenze, Dipartimento di Matematica per le Decisioni. Seminar of CEOC, October 27, 2006.

- **Organized conferences**

1. Eugénio A. M. Rocha was member of the Organizing Committee of the International Conference "Views on ODEs", 21-24 June 2006, Aveiro, Portugal (in honour of Arrigo Cellina and James A. Yorke).
2. Eugénio A. M. Rocha was Chairman of the Organizing Committee of the International Conference "Communicating Mathematics in the Digital Era", 15-18 August 2006, Aveiro, Portugal.

#### 4.7 List of MSc dissertations

1. Andreia M. F. Louro, Computação Simbólica em Maple no Cálculo das Variações, MSc dissertation in Mathematics, July 2006 (supervised by Delfim F. M. Torres).
2. Joana F. Costa, Teorema de Noether do Cálculo das Variações e do Controlo Óptimo na Economia, MSc dissertation in Mathematics, October 2006 (supervised by Delfim F. M. Torres).

#### 4.8 Computational Applications

Title: Automatic Computation of Conservation Laws in the Calculus of Variations and Optimal Control

Authors: Paulo D. F. Gouveia and Delfim F. M. Torres

Application Type: Maple Worksheet

Publish date: July, 2006

Language: English

Available from the Maple Application Centre:

[http://www.maplesoft.com/applications/app\\_center\\_view.aspx?AID=1983](http://www.maplesoft.com/applications/app_center_view.aspx?AID=1983)