Página principal
Main page

Lista de candidaturas
Application list

Formulário de candidatura
Application form

Curriculum Vitae
Curriculum Vitae

Declaração de Compromisso
Statement of agreement

Inquérito OCES
Questionnaire OCES

Concursos anteriores
Former applications

Formulário de candidatura
Application form

Concurso para a atribuição de Bolsas Individuais 2006
Grant proposal for individual study 2006
Aberto de 01-03-2006 a 31-03-2006
opened from 01-03-2006 to 31-03-2006

Referência Reference	Data de registo Registry date	Lacrado Submited
SFRH/BD/27272/2006	Registado a 01-03-2006 (09:18) Registered at 01-03-2006 (09:18)	**Lacrado a 14-04-2006 (14:07)** **Submitted at 14-04-2006 (14:07)**

Identificação do candidato
Candidate's personal information

Nome completo
Full name
Cristiana João Soares da Silva

Número de identificação fiscal (NIF)
Taxpayer identification number
219826021

Data de nascimento
Birth date
20-07-1980

Sexo
Gender
F

Naturalidade (Concelho)
Birth place
Batalha

Bilhete de identidade
National identity card No.
11765024(Emitido em26-06-2002)

Arquivo de Identificação
Arquivo de Identificação
Leiria

País de Nacionalidade
Birth place
PORTUGAL

Morada
Address
Rua Casal Cantiga, nº16, Céla de Cima

Código postal
Zip code
2440 - 058

Localidade
City
Batalha

País de residência
Country of residence
PORTUGAL

Telefone (casa)
Phone number (home)
244765873

Telefone (emprego)
Phone number (work)
244765873

Telemóvel
Mobile phone
919456113

Email
Email
cjoaosilva@yahoo.com.br

Habilitações académicas
Academic degrees

Ano Year	Grau académico Academical Degree
2005	MESTRADO

Título da tese (se aplicável)
Thesis title (if applicable)
Abordagens do Cálculo das Variações e Controlo Óptimo ao Problema de Newton de Resistência Mínima

Domínio Científico
Scientific Domain
Matemática

Instituição que atribuiu o grau
Institution granting the academic degree
Universidade de Aveiro

Classificação
Classification
Aprovada (sistema binário: aprovado/reprovado)

Ano Year	Grau académico Academical Degree
2003	LICENCIATURA

Título da tese (se aplicável)
Thesis title (if applicable)

Domínio Científico
Scientific Domain
Matematica

Instituição que atribuiu o grau
Institution granting the academic degree
Universidade de Coimbra - Faculdade de Ciências e Tecnologia

Classificação
Classification
15

Actividades anteriores e situação actual em termos científicos e/ou profissionais
Previous and current scientific and/or professional activities

Período Period	Cargo ou categoria Position or category	Instituição Institution
2002-2003	Professora estagiária	Escola EB 2,3 Dr. José dos Santos Bessa
1 Fevereiro a 30 Abril de 2006	Bolseira da Fundacao Calouste Gulbenkian	Mathématiques, Labo. AN-EDP, UMR 8628 - Universite Paris-Sud XI - France

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1. Informações sobre a candidatura
1. Application form information

Tipo de Bolsa
Type of Fellowship
Bolsa de Doutoramento
Doctoral Grant

Domínio Científico Principal
Main Scientific Domain
Matemática
Mathematics

Local de realização da Bolsa
Location of fellowship activities
Mista
Both in Portugal and Abroad

---

2. Endereço para correspondência
2. Mailing address information

Morada
Address
Rua Casal Cantiga, 16 - Céla de Cima

Código postal ZIP code	Localidade City
2440-058	Batalha

País
Country
PORTUGAL

Telefone Phone	Fax Fax
244765873	244765873

Email
Email
cjoaosilva@yahoo.com.br

---

3. Procurador do candidato
3. Candidate's representative

Nome completo
Full name
Delfim Fernando Marado Torres

Morada
Address
Departamento de Matemática, Universidade de Aveiro

Código postal ZIP code	Localidade City
3810-193	Aveiro

País
Country
PORTUGAL

Telefone (casa) Phone number (home)	Telefone (emprego) Phone number (work)
	234 370 668

Telemóvel Mobile phone	Email Email
96 30 636 70	delfim@mat.ua.pt

Observações
Notes

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4. Programa de trabalhos
4. Working programme

4.1. Título do programa de trabalhos
4.1. Title of the working programme

Optimal syntheses of nonlinear optimal control problems involving state constraints, and conjugate points

Domínio Científico
Scientific Domain

Mathematics, Optimal Control

Data de início do programa de trabalhos Work programme starting date	Duração (meses) Duration (month)
01-10-2006	48

Data de início pretendida para a bolsa Fellowship starting date	Duração (meses) Duration (month)
01-10-2006	48

Permanência no estrangeiro com início em Periods of permanence abroad	Duração (meses) Duration (month)
01-10-2006	9
01-10-2007	9
01-10-2008	9
01-10-2009	9

4.2. Sumário
4.2. Abstract

In optimal control problems, three main basic questions have to be answered (see e.g. [Torres'04]): Does an optimal solution exist? How can one restrict the candidates for optimality by way of necessary conditions? Is a candidate found in this way indeed optimal (in a local/global sense)? For the problem of existence of optimal trajectories, fairly general results are known (see e.g. [Lee,Markus'67]), which cover a wide range of realistic problem situations, involving any type of constraint. In contrast, theories of necessary and sufficient conditions for optimality lack a similar completeness of results. If state constraints are moreover imposed, the situation is widely open. The Pontryagin maximum principle [Pontryagin et.al.'62] gives first order conditions for optimality, whenever there is no state constraint, or in the case of constraints of order one. For more general constraints, other maximum principles exist (see e.g. [Jacobson,Lele,Speyer'71], [Maurer'77]). However, in most cases, there exists a significant gap between the structure of extremals (i.e., trajectories that satisfy the necessary conditions for optimality) and the structure of optimal trajectories in an optimal synthesis. Our aim is to contribute in closing this gap.

4.3. Estado da Arte
4.3. State of the art

In the eighties, much progress has been made in closing the gap between necessary and sufficient conditions, in dimensions two and three, when there is no state constraint. The main results in that direction have been obtained in [Krener,Schattler'89], [Schattler'88], [Sussmann'87], and concern the qualitative structure of small-time reachable sets for autonomous control-affine systems. Later, with [Bressan,Piccoli'98] and [Piccoli'96], more precise results were obtained on two-dimensional manifolds (see also the book of [Boscain,Piccoli'04]). These results describe the small-time reachable sets, and hence, the local structure of optimal trajectories, in low dimensions, in function of the Lie bracket configuration of the vector fields that define the control system. For autonomous control-affine systems subject to a pure state constraint of the inequality type, the first (local) results appear in [Bonnard,Faubourg,Launay,Trélat'03]. They have been motivated by a concrete real-life optimal control problem.

4.4. Objectivos
4.4. Objectives

The main objectives of the proposed PhD project are four: (i) to extend the previously known results on the local structure of optimal trajectories, in dimensions two and three, to the case of higher-order dimensions (to investigate the existence of singular trajectories; occurrence of the Fuller phenomenon; etc); (ii) to obtain global results (to investigate the conjugate points along the extremal trajectories; etc); (iii) to extend the conjugate point theory for control systems subject to state constraints (to investigate the possibility of extending the classical Morse theory to quadratic forms defined on semi-spaces; to investigate necessary and/or sufficient second-order conditions for optimality; to investigate on a possible theory of envelopes; etc); (iv) to apply the obtained results to concrete optimal control problems with relevance in applications (to investigate efficient and stable numerical methods; etc).

4.5. Descrição detalhada

4.5. Detailed description

The first part of the PhD subject consists in going on with the results of [Bressan,Piccoli'98],[Bonnard,Faubourg,Launay,Trélat'03], [Torres'03], [Boscain,Piccoli'04], and, in particular, in extending the previously obtained results to the case of higher dimensions. The problem is challenging, because the structure of extremals can be extremely complicated, in particular due to the generic existence of singular trajectories, and to the occurrence of the Fuller phenomenon (see [Kupka'90]). On the other part, this question is crucial for the concrete applications of the optimal control theory, since it is an essential preliminary theoretical step in order to implement numerical methods (as the shooting method, see [Trélat'05]).

Once these local optimal syntheses have been determined, another very important question is to make them global. A usual tool to achieve this is the conjugate point theory. Roughly speaking, the first conjugate time along an extremal trajectory is the times at which the trajectory ceases to be optimal. However, up to now, the results of that theory (see for instance [Agrachev,Sachkov'04], [Ioffe,Tihomirov'79], [Sarychev'80], and [Sussmann'89]) concern the case where there does not exist any state constraint. No results exist when there are some state constraints. From the numerical point of view, the determination of conjugate points consists in testing a determinant computed from a variational system attached to the control system. Recently, efficient algorithms have been written, implementing this computation (see [Bonnard,Caillau,Trélat'05], and the routine "cotcot", available on the web), that have been used for aeronautic control issues.

The second part of the PhD subject consists in developing the conjugate point theory for control systems submitted to state constraints. From the theoretical point of view, two approaches seem to be promising. First, one way is to extend the classical Morse theory to quadratic forms defined on semi-spaces, and to deduce necessary and/or sufficient second-order conditions for optimality, in the case of state constraints. Another approach is to adapt the theory of envelopes (see [Sussmann'89]) to the case of state constraints. Hence, the work is both theoretical, and numerical, since the obtained conditions then have to be implemented, and the software "cotcot" has to be extended to this framework.

4.6. Anexos
4.6. Attachments

4.7. Referências
4.7. References

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[Bonnard,Caillau,Trélat´05] B. Bonnard, J.-B. Caillau, E. Trélat, Cotcot: short reference manual, Technical report RT/APO/05/1, March 2005, http://www.n7.fr/apo

[Bonnard,Faubourg,Launay,Trélat´03] B. Bonnard, L. Faubourg, G. Launay, E. Trélat, Optimal control with state constraints and the space shuttle re-entry problem, J. Dynam. Cont. Syst. 9(2), 2003, 155-199.

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[Ioffe,Tihomirov´79] A. D. Ioffe, V. M. Tihomirov, Theory of extremal problems, Studies in Mathematics and its Applications, 6, North-Holland Publishing Co., Amsterdam-New York, 1979.

[Jacobson,Lele,Speyer´71] D. H. Jacobson, M. M. Lele, J. L. Speyer, New necessary conditions of optimality for control problems with state-variable inequality constraints, J. Math. Anal. Appl. 35, 1971, 255-284.

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[Kupka´90] I. Kupka, The ubiquity of Fuller´s phenomenon, Nonlinear controllability and optimal control, Monogr. Textbooks Pure Appl. Math. 133, Dekker, New York, 1990, 313-350.

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[Pontryagin et.al.'62] L. S. Pontryagin, V. G. Boltyanskii, R. V.

Gamkrelidze and E. F. Mishchenko, The mathematical theory of optimal processes, Interscience Publishers John Wiley and Sons, Inc., New York-London, 1962.

[Sarychev'80] A. V. Sarychev, Index of second variation of a control system, Mat. Sb. (N.S.) 113(155) (1980), no. 3(11), 464--486, 496.

[Schattler'88] H. Schattler, The local structure of time optimal trajectories in dimension 3, SIAM J. Control Optim. 26(4), 1988, 899-918.

[Sussmann'87] H. J. Sussmann, The structure of time-optimal trajectories for single-input systems in the plane: the C infinity nonsingular case, SIAM J. Control Optim. 25(2), 1987, 433-465.

[Sussmann'89] H. J. Sussmann, Envelopes, high-order optimality conditions and Lie brackets, Proceedings of the 28th IEEE Conference on Decision and Control, Vol. 1-3 (Tampa, FL, 1989), 1107-1112, New York, 1989.

[Torres'03] D. F. M. Torres, Lipschitzian regularity of the minimizing trajectories for nonlinear optimal control problems. Math. Control Signals Systems 16 (2003), no. 2-3, 158-174.

[Torres'04] D. F. M. Torres, Carathéodory equivalence, Noether theorems, and Tonelli full-regularity in the calculus of variations and optimal control, J. Math. Sci. (N. Y.) 120 (2004), no. 1, 1032-1050.

[Trélat'05] E. Trélat, Optimal control: theory and applications, Vuibert, 2005 (in French).

5. Condições de acolhimento
5. Host conditions

Nacionalidade da instituição que confere o grau
Nationality of the institution granting the academic degree
Portuguesa / Portuguese

Instituição que confere o grau
Institution granting the academic degree
Universidade de Aveiro

Morada
Address
Campus Universitario de Santiago

Código postal
Zip code
3810-193

Localidade
City
Aveiro

Telefone
Phone Number
234370359

email
email
www.ua.pt

Fax
fax
234382014

Instituicao de Acolhimento 1
Host Institution
Université Paris-Sud (Orsay, France)
Responsável pela formação
Scientific Supervisor
Emmanuel Trélat
Departamento
Department
Mathématiques, Labo. AN-EDP, UMR 8628
Morada
Address
Bat. 425 , Université Paris-Sud XI
Código postal
Zip code
91405
Localidade
City
Orsay ced
País
Country
FRANCE
Telefone
Phone Number
(+33) 169156
Email
Email
catherine.poupon@math.u-psud.fr

Instituicao de Acolhimento 2
Host Institution
Universidade De Aveiro
Responsável pela formação
Scientific Supervisor
Delfim Fernando Marado Torres
Departamento
Department
Departamento de Matematica
Morada
Address
Campus Universitario de Santiago

Código postal **Zip code**	**Localidade** **City**
3810-193	Aveiro

País
Country
PORTUGAL

Telefone **Phone Number**	**Email** **Email**
234370359	www.ua.pt

---

6. Cartas de referência
6. Reference letters

Nome
Name
Professor Doutor Fernando A. C. C. Fontes
Instituição
Institution
Universidade do Minho - Departamento de Matematica para a Ciencia e Tecnologia

Nome
Name
Professor Doutor Alexander Plakhov
Instituição
Institution
Departamento de Matematica da Universidade de Aveiro

Nome
Name
Professor Doutor Emmanuel Trélat
Instituição
Institution
Labo. Math., UMR 8628 Bat. 425, Univ. Paris-Sud, Orsay

Nome
Name
Professor Doutor Guy David
Instituição
Institution
Directeur du Laboratoire de Mathématique, Bat. 425, UMR 8628, Univ. Paris-Sud, Orsay

---

7. Bolsas anteriores
7. Previous fellowships

Ano de conclusão **Year of completion**	**Ref. da Bolsa** **Fellowship Ref.**
2006	Bolsa de estudo de curta duracao no estrangeiro - sob a orientaçao do Prof. Doutor Emmanuel Trélat

Instituição
Institution
Fundacao Calouste Gulbenkian
Período
Period
De 1 de Fevereiro a 30 de Abril de 2006

Ano de conclusão **Year of completion**	**Ref. da Bolsa** **Fellowship Ref.**
2005	Bolsa de Mestrado

Instituição
Institution
Fundacao Calouste Gulbenkian
Período
Period
2003-2005

Ano de conclusão **Year of completion**	**Ref. da Bolsa** **Fellowship Ref.**
2003	Bolsa a estudantes do ensino secundario e superior

Instituição

Institution
Fundacao Calouste Gulbenkian
Período
Period
1997-2003

---

8. Actividade Profissional
8. Professional activity

Tenciona manter alguma actividade profissional durante o período da bolsa?
Do you intend to maintain any professional activity during the fellowship period?
Não
No

Financiamento do Fundo Social Europeu e de fundos nacionais do MCTES