EPCO'015

Encontro Português de Controlo Ótimo 2015

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Escola de Ciências, Universidade do Minho
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It is our pleasure to welcome you at the Portuguese Meeting on Optimal Control 2015 - EPCO 2015, held on September 15th, 2015 at Sciences School of University of Minho, Guimarães, Portugal.

EPCO 2015 will provide an excellent opportunity for presenting new results and to discuss the latest research and developments in the field of optimal control. As in previous editions, this is an informal meeting seeking the exchange of knowledge and ideas among participants.

The meeting will cover a broad range of topics including:

- Application of optimal control to energy, medicine, robotics, economics, biology, etc,
- Optimality conditions
- Sensitivity analysis
- Hamilton-Jacobi approach
- Stabilization methods for nonlinear systems
- Model Predictive Control
- Perturbed Systems
- Differential Games
- Numerical Approaches; Solvers

The language of this meeting will be English. In order to ensure that all participants have the opportunity to share their results, all abstracts will be presented in one of two formats: oral presentation or poster.

Contents

Programme

09h15-09h50 Registration:: room EC1.09 (ground floor)

09h50-10h00 Conference opening:: room EC.2.14 (1st floor)

Chair: Fernando A.C.C. Fontes

10h00-10h30 Direct-multisearch for multiobjective optimization
A. Ismael F. Vaz (Departamento de Produção e Sistemas, Escola de Engenharia, Universidade do Minho)

10h30-10h50 Optimal control and cost-effectiveness analysis for a tuberculosis model
Cristiana J. Silva (CIDMA, Universidade de Aveiro)

10h50 -11h10 NMB target level tracking based on an optimal control problem
Juliana Almeida (Faculdade de Engenharia, Universidade do Porto)

11h10-11h40 Coffee-Break

Chair: António Pedro Aguiar

11h40-12h00 A virtual target approach for trajectory optimization of autonomous robotic vehicles
Alessandro Rucco (SYSTEC-ISR & FEUP, Universidade do Porto)

12h00-12h20 From human motor control to robot movement control
Eliana Costa E Silva (Centro Algoritmi, Universidade do Minho & CIICESI, ESTGF - Instituto Politécnico do Porto)

12h20-12h40 A numerical approach to a control problem in passive tracer advection by point vortex flow
Carlos Balsa (Instituto Politécnico de Bragança)

12h40-13h00 A discretization method to solve fractional variational problems with dependence on Hadamard derivatives
Nuno R. O. Bastos (CIDMA, UA & Departamento de Matematica, ESTG, Instituto Politécnico de Viseu)

13h00-15h00 Lunch

Chair: G.V. Smirnov

15h00-15h20 Application of model predictive control in dieting control
Amélia Caldeira (SYSTEC-ISR & FEUP, Universidade do Porto)

15h40-16h00 Optimal control and model predictive control of kite power systems
Fernando A.C.C. Fontes (Faculdade de Engenharia, Universidade do Porto)

15h20-15h40 An adaptive mesh refinement method for state constrained optimal control problems
Luís Tiago Paiva (Faculdade de Engenharia, Universidade do Porto)

16h00-16h20 Optimal control problems for a system of linear diffusion equations
Paulo Rebelo & Silvério Rosa (Universidade da Beira Interior)

16h20-16h50 Coffee Break

16h50-17h00 Poster Session

Chair: Sílvio Gama

17h00-17h20 An optimal control approach to higher-order variational problems of Herglotz type
Simão P. S. Santos (CIDMA, Universidade de Aveiro)

17h20-17h40 On optimal latching control for a floating oscillating water column wave energy converter
João C. C. Henriques (IDMEC & IST, Universidade de Lisboa)

17h40 -18h00 Optimal control for a hydroelectric power station problem
M. Margarida A. Ferreira (Faculdade de Engenharia, Universidade do Porto)

Coffee-breaks will take place at room EC.2.16 (1st floor).

Lunch is planned at the *Restaurante Universitário* of the University Campus.

Abstracts

Talk 1.
Title. NMB target level tracking based on an optimal control problem
Juliana Almeida, Luís Tiago Paiva, Teresa Mendonça, Paula Rocha
(Faculdade de Engenharia, Universidade do Porto)

Abstract. During a surgical procedure the anaesthesia enables a patient to tolerate the pain and to avoid movement responses as a result of a surgical stimuli. The loss of the capability to move is obtained by the administration of muscle relaxants, e.g., atracurium or rocuronium and is monitored by the neuromuscular blockade (NMB) level. This level is measured from a muscle response at the hand of the patient evoked by a stimulation of the adductor pollicis muscle through supra maximal train–of–four stimulation of the ulnar nerve. More concretely, the NMB level corresponds to the first single response calibrated by a reference twitch, ranging between 100% (full muscular activity) and 0% (total paralysis). In the anaesthesia practice, an initial dose of anaesthetics are administered following standard dosing guidelines, the patient's response is observed and adjustments are made to achieve the desired target level. In order, to automate this process, a control law to control the NMB level obtained by solving an optimal control problem (OCP) is presented here. The OCP is solved using numerically methods.
The OCP is formulated in the following way:

$$\begin{aligned} &\min_{u(t)} \int_0^T q\,(y(t)-y^*)^2 + ru^2(t)dt \\ &\text{s.t.}\dot{x}(t) = Ax(t) + Bu(t) \\ &y(t) = \frac{100}{1+\left(\frac{x_3(t)}{C_{50}}\right)^{\gamma}} \\ &x(0) = x_0 \ \text{ and } \ x(T) = x^e \end{aligned}$$

The obtained results show that the NMB level achieves the desired level. More details will be shown at the conference.

Talk 2.
Title. A numerical approach to a control problem in passive tracer advection by point vortex flow Carlos Balsa, Sílvio M.A. Gama
(Instituto Politécnico de Bragança)

Abstract. Point vortices are singular solutions of the two-dimensional incompressible Euler equations. These solutions correspond to the limiting case where the vorticity is completely

concentrated on a finite number of spatial points each with a prescribed strength/circulation. By definition, a passive tracer is a point vortex with zero circulation.
In our case, we consider the advection of one passive tracer by N point vortices in the unbounded plane. In this context, we present the formulation of certain number of control problems, as well as the results of some numerical experiments showing the existence of optimal controls for the cases of $N = 1$, $N = 2$, $N = 3$ and $N = 4$ vortices. More precisely, we look for the optimal trajectories that minimize the objective function that correspond to the energy expended in the control of the trajectories. The restrictions are due to (i) the ordinary differential equations that govern the displacement of the passive particle around the point vortices, (ii) the available time T to go from the initial position z_0 to the final destination z_f, and (iii) the maximum absolute value $u_{\max}$ that is imposed on the control variables. The latter consist in staircase controls, i.e. the control is written as a finite linear combination of characterisc functions on the real interval.

Talk 3.
Title. A discretization method to solve fractional variational problems with dependence on Hadamard derivatives
Nuno R. O. Bastos, Ricardo Almeida, Delfim F. M. Torres
(CIDMA, UA & Departamento de Matemática, ESTG, Instituto Politécnico de Viseu)

Abstract. In this talk we provide a fast and simple method to solve fractional variational problems with dependence on Hadamard fractional derivatives. Using a relation between the Hadamard fractional operator and a sum involving integer-order derivatives, we rewrite the fractional problem into a classical optimal control problem. The latter problem is then solved by application of standard numerical techniques. We illustrate the procedure with an example.

Talk 4.
Title. Application of model predictive control in dieting control
Amélia Caldeira, Diogo Bastos, Maria do Rosário de Pinho
(SYSTEC-ISR & FEUP, Universidade do Porto)

Abstract. Millions of people around the world suffer from too much weight. It is well known that, in general, overweight people consume more calories than they use.
Any dynamic mathematical model to approach the human metabolism and to integrate knowledge about how the human body responds in terms of weight to changes of diet and physical activity is complex. In this work we test one such model. Using a weight reference trajectory (to achieve weight loss) we compare data at the time of assessment with the initial estimates of weight loss in a specific time frame. We apply the MPC technique to alert and define a new plan from such point.
The weight reference trajectory is a patchwork reference trajectory. First we use a given weight reference trajectory. If, at the time of assessment, the real weight deviates from the reference one, the reference trajectory is replaced by the solution of optimal control problem.

Talk 5.
Title. From human motor control to robot movement control
Eliana Costa E Silva, Estela Bicho, Wolfram Erlhagend, M. Fernanda Costa, Ruud Menlenbroeke
(Centro Algoritmi, Universidade do Minho & CIICESI, ESTGF - Instituto Politécnico do Porto)

Abstract. Robots are becoming more and more part of our daily life. For this reason they must be able to achieve high levels of cooperation and communication in order to be accepted by potential human users. Although human-like morphology is an important characteristic for these robots, human-like movement is recognized as a key feature for meaningful and natural interactions since they allow the user to more easily interpret movements of the robot as goal-directed actions. In this talk we report about the movement planning model for an anthropomorphic robot we have developed that is inspired by the Posture-Based Motion Planning Model proposed by Rosenbaum and colleagues to explain human upper limb movements. We present arm-hand movements of an anthropomorphic robot in different tasks and different obstacle avoidance scenarios. The results smooth, fluent and collision-free movements that qualitatively reflect main characteristics of hand and arm trajectories observed in experiments with humans.

Talk 6.
Title. Optimal control for a hydroelectric power station problem
M. Margarida A. Ferreira, G.V. Smirnov
(Faculdade de Engenharia, Universidade do Porto)

Abstract. A control problem for a cascade of hydroelectric power stations is analysed. The model considered is a simple version of real life problems in hydroelectric systems and its formulation involves indefinite quadratic cost, control constraints and also pure state constraints. Optimal trajectories for some particular cases are investigated.

Talk 7.
Title. Optimal control and model predictive control of kite power systems
Fernando A.C.C. Fontes, Luís Tiago Paiva
(Faculdade de Engenharia, Universidade do Porto)

Abstract. We consider continuous–time optimal control and model predictive control problems of kite power systems [1]. Kite power systems (KPS) not only provide interesting and challenging optimal control problems, but are also a promising technology to exploit renewable energy for electrical energy production. A KPS consists of a tethered kite flying in a crosswind direction, connected to a drum and an electrical generator on the ground. As the kyte pulls the tether, the wind energy at high altitude is transmitted to the ground by unwinding the cable around the drum and thereby driving the electrical generator.
The solution of the OCP is challenging: it is highly nonlinear, involves a nonholonomic systems and might have multiple local optima. To solve these problems we consider a time–mesh that is adaptively refined to achieve a desired error threshold. Details of this technique and its use in other nonlinear systems are stated in [2],[3].
The refinement algorithm is extended to solve a sequence of optimal control problems in a Model Predictive Control (MPC) scheme. In this extension, we consider a time–dependent stopping criterion for the mesh refinement algorithm with different levels by imposing a higher accuracy requirement in the initial parts of each horizon, which are more relevant in MPC. The use of adaptive refinement in real–time optimization schemes, such as MPC, enables the possibility of obtaining a solution even when the optimization has to be interrupted at an early stage.

References
[1] Luís Tiago Paiva, Fernando A.C.C.Fontes. Mesh–Refinement Strategies for Fast Optimal Control and Model Predictive Control of Kite Power Systems. in The International Airborne Wind Energy Conference 2015, pp. 101, Delft, June 2015.