Título das sessões:

Optimal Control. Theory and Applications. Parte I.
Optimal Control. Theory and Applications. Parte II.

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Breve descrição dos objetivos da sessão

O controlo ótimo tem sido de importância fundamental em engenharia de projeto desde há várias décadas. Hoje em dia é ferramenta de reconhecida eficácia em diferentes áreas tais como robótica, sistemas de energia, sistemas biológicos, sistemas económicos, etc.

A necessidade de resolver problemas reais formulados como problemas de controlo ótimo tem sido uma força motriz não só para o desenvolvimento da teoria do controlo e otimização, mas também para desenvolvimento de novos métodos computacionais. A literatura é rica em técnicas de controlo ótimo concebidas para extrair informações úteis no sentido de caracterizar ou ajudar a caracterizar a solução dos problemas. Nos últimos anos têm surgido vários "solvers" que permitem o tratamento numérico de problemas de grande complexidade e/ou dimensão.

Nestas 2 sessões são apresentados trabalhos na área do Controlo Ótimo, focando tanto desenvolvimentos de índole teórico como aplicações.

Optimal Control. Theory and Applications. Part I

1. **Sofia Lopes** (UM), *Mathematics applied to irrigation systems.*

   Abstract: In this presentation, we study irrigation systems using a mathematical model and address a minimal water consumption problem. Given the importance of water use in irrigation systems, we discuss the advantages of using optimal control in this type of problems.

2. **Juliana Almeida** (FEUP), *Optimal control approach applied to general anaesthesia.*

   Abstract: We present a state-feedback design method to control the amount of propofol during a general anaesthesia. This problem can be associated with an optimal control problem (OC) with a positivity constraint in the input signal. To solve this problem the OCP is relaxed into a Semi-definite program and then solved.

3. **Luís Tiago Paiva** (FEUP-SYSTEC), *Adapting a time-mesh to each Optimal Control Problem.*

   Abstract: Over the past decades, direct methods have become increasingly useful when computing the numerical solution of nonlinear optimal control problems (OCP). When applying these methods, the control and the state variables are discretised selecting a mesh of the time interval.
   The first challenge is to select a mesh that is suitable to solve the OCP. This is the topic that

we address.
We propose a time-mesh refinement algorithm where the refinement strategy is driven by the information given by the dual variables and it stops according to the information given by the primal variables. This technique provides an adapted time-mesh for each OCP. The results show a favourable comparison against the traditional equidistant-spaced time-mesh methods, including the ones using discrete-time models, contributing to significant savings in memory and computational time and cost without compromising the accuracy of the solution.

4. **Alessandro Rucco**, (FEUP-SYSTEC), *A Moving Path Following Approach for Trajectory Optimization of Autonomous Robotic Vehicles.*

   Abstract: The main aim of this talk is to present and discuss novel numerical approaches to the design of (local) optimal trajectories of autonomous robotic vehicles. The highlighted contribution is part of a broader research work developed in the last years to design motion planning algorithms for heterogeneous autonomous vehicles in dynamic environments. Specifically, in this talk we first introduce the use of a Virtual Target Vehicle (VTV) approach in the development of optimal control based methods for trajectory optimization. Given a desired (stationary) path with a specified desired velocity profile, we are interested in computing a feasible trajectory (i.e., it satisfies the dynamics and the constraints) that best approximates the desired path. Second, we extend the VTV approach to the case of desired moving (non-stationary) path. Given a desired path with respect to a possible moving vehicle, our goal is to compute the (local) optimal feasible trajectory that best approximates the desired moving path with a specified speed profile assigned on it. In both approaches (i.e., stationary and moving paths), we set up a suitable optimal control problem where the L2 distance between actual and desired trajectories is minimized. We solve the optimal control problem numerically by using the PRojection Operator based Newton method for Trajectory Optimization (PRONTO). Inequality constraints (state, control, and mixed) are taken into account through the use of ex- tended barrier functionals which are quite effective for the non-convex constraints that arise in our ongoing work for cooperating/cooperative vehicles. Finally, we examine the performance of the proposed approaches by providing numerical computations for trajectory planning of aerial vehicles with applications to target tracking of marine/ground vehicles. We highlight and discuss some promising aspects, as well as pitfalls and drawbacks.

Optimal Control. Theory and Applications. Part II

5. **Manuel Guerra** (ISEG), *Optimal control problems of low growth*.

   Abstract: We study Lagrange variational problems with convex integrand and control-affine dynamics with non-commuting controlled vector fields. It is known that if a super-linear growth condition for the integrand is not satisfied, then classical minimizers of the problem may cease to exist and one is compelled to seek for generalized minimizers. It can be shown that such optimal control problems can be extended into the space of Fréchet generalized controls and, under mild assumptions, a generalized Fréchet minimizer is guaranteed to exist. In this work we discuss optimality conditions and structure of generalized Fréchet minimizers.

6. **Miguel Oliveira** (UM), *Complexity bounds for path-following method applied to a problem of calculus of variations with quadratic integrand*.

   Abstract: We obtain complexity bounds for path-following method applied to a problem of calculus of variations with quadratic integrand. The approach is based on explicit estimate for Lipschitz constant of solution to the problem

7. **Teresa Grilo** (FCUP), *Fish locomotion driven by point vortices.*

Abstract: Em diversas áreas da engenharia os problemas de controlo ótimo são de extrema importância para o avanço e desenvolvimento tecnológico. A área da robótica, em particular o movimento dos peixes mecânicos, foi o que nos inspirou para estudar este tipo de problemas de controlo. Assim, apresentaremos um modelo que mimica o movimento de um peixe quando este se desloca de um ponto inicial até um determinado ponto final.
Ao longo do seu movimento, o peixe estará sob a ação de dois vórtices pontuais, criados através da movimentação da sua cauda, que perderão intensidade ao longo do tempo, o que o obrigará a criar um novo vórtice em determinado instante. Aplicando o método de multiprocessos e o princípio do máximo de Pontryagin, obteremos a trajetória ótima no sentido em que corresponde à obtida minimizando o consumo energia.

8. **M. Margarida A. Ferreira** (FEUP-SYSTEC), *On the sufficiency of Pontryagin's maximum principle.*

Abstract: Sufficient conditions of optimality for an optimal control problem are under attention. We introduce a refined maximum principle condition that for certain classes of non convex problems, involving affine control systems with a polyhedral set of controls, guarantees weak local optimality of control processes. Examples will be presented to illustrate this sufficient condition.