Plenary Speakers

Sílvia Barbeiro (CMUC, Department of Mathematics, University of Coimbra)

"Learning optimized cross-diffusion reaction systems"

Abstract: After the pioneering work of Keler and Segel in the 1970s cross-diffusion models became very popular in biology, chemistry and physics to emulate systems with multiple species. From a mathematical point of view, cross-diffusion models are described by time-dependent partial differential equations (PDE) of diffusion or reaction-diffusion type, where the diffusive part involves a general nonlinear non-diagonal diffusion matrix. This leads to a strongly coupled system where the evolution of each dependent variable depends on itself and on the others in a way governed by the diffusion matrix. The selection of the optimal coefficients and influence functions that rule the associated PDE system is always a critical question when modeling real phenomena.

In this talk we will focus on nonlinear cross-diffusion systems for image filtering. The use of two scalar fields has the goal of distributing the features of the image and governing their relations. The parameters of the model that lead to the most effective methods vary depending on the acquisition methods, the nature of the images and the associated noise profile. So, how can such parameters be derived? We propose the use of deep learning techniques on already established non-linear cross-diffusion schemes for image filtering in order to optimize the parameters for each specific task. In particular, we use a back-propagation technique in order to minimize a cost function related to the quality of the denoising process while we ensure stability during the learning procedure. Consequently, we obtain improved image restoration models with solid mathematical foundations. The learning framework and resulting models will be presented along with related numerical results and image comparisons. The proposed mathematical tool set can be transferred to a broad scope of problems.

Fernanda Cipriano (CMA, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa)

"Optimal control of stochastic second grade fluids"

Abstract: This presentation deals with well-posedness and optimal control for two dimensional stochastic second grade fluids. The deterministic equation is perturbed by a multiplicative white noise and supplemented with Navier-slip boundary conditions.

The control acts through an external stochastic force or as a feedback type control. In the former case, we show that the Gâteaux derivative of the control to state map is a stochastic process being the unique solution of the stochastic linearized state equation. The well-posedness of the corresponding stochastic backward adjoint equation is also established, allowing to derive the first order optimality condition.

In the feedback case, we establish the existence of an optimal control and using the Galerkin approximations, we show that the optimal cost can be approximated by a sequence of finite dimensional optimal costs, showing the existence of the so-called ε-optimal feedback control.

Plenary Speakers

Irene Fonseca (Carnegie Mellon University - USA)

"Mathematical Analysis of Novel Advanced Materials"

Abstract: Quantum dots are man-made nanocrystals of semiconducting materials. Their formation and assembly patterns play a central role in nanotechnology, and in particular in the optoelectronic properties of semiconductors. Changing the dots' size and shape gives rise to many applications that permeate our daily lives, such as the new Samsung QLED TV monitor that uses quantum dots to turn "light into perfect color"!

Quantum dots are obtained via the deposition of a crystalline overlayer (epitaxial film) on a crystalline substrate. When the thickness of the film reaches a critical value, the profile of the film becomes corrugated and islands (quantum dots) form. As the creation of quantum dots evolves with time, materials defects appear. Their modeling is of great interest in materials science since material properties, including rigidity and conductivity, can be strongly influenced by the presence of defects such as dislocations.

In this talk we will use methods from the calculus of variations and partial differential equations to model and mathematically analyze the onset of quantum dots, the regularity and evolution of their shapes, and the nucleation and motion of dislocations.

Patrícia Gonçalves (Instituto Superior Técnico, Universidade de Lisboa)

"Deriving fractional PDEs from microscopic stochastic models"

Abstract: In this seminar I will describe the derivation of certain laws that rule the space-time evolution of the conserved quantities of stochastic processes. The random dynamics conserves a quantity (as the total mass) that has a non-trivial evolution in space and time. The goal is to describe the connection between the macroscopic (continuous) equations and the microscopic (discrete) system of random particles. The former can be either PDEs or stochastic PDEs depending on whether one is looking at the law of large numbers or the central limit theorem scaling; while the latter is a collection of particles that move randomly according to a transition probability. I will focus on a model for which we can obtain a collection of (fractional) reaction-diffusion equations given in terms of the regional fractional Laplacian with different types of boundary conditions.

Plenary Speakers

Margarida Melo (CMUC, Universidade de Coimbra and Roma Tre)

"Compactifications of algebro-geometric moduli spaces and tropicalizations"

Abstract: In algebraic geometry, the existence of moduli spaces parametrizing certain objects with fixed geometric type is of central importance.

In fact, one can use the geometry of the moduli space itself to study the geometry of the objects it parametrizes.

Since most tools in algebraic geometry work for compact spaces, it is important to construct compactifications of the moduli spaces, and ideally describe them as moduli spaces of degenerate objects themselves.

In the last few years, there were breakthrough works aiming to systematic realizing a topological retraction of the boundary of some of these compactifications as parameter spaces of tropical objects of similar (but simpler) nature.

In the talk, I will illustrate these phenomena for the moduli space of curves of given genus and other related spaces and give some hints on possible applications of these constructions.

Teresa Monteiro Fernandes (Faculdade de Ciências, Universidade de Lisboa)

"An overview on *D*-modules with a view on Riemann-Hilbert correspondences"

Abstract: I shall start by giving some light on *D*-module theory on real analytic and complex manifolds illustrating with simple examples. Next, I will explain Riemann-Hilbert problem in this context as well as the construction of Kashiwara's Riemann-Hilbert functor as a quasi-inverse to the solution functor for regular holonomic modules (more examples!). Then I will explain how this construction can be adapted to a relative (smooth) framework, where D_X is replaced by the sheaf of relative differential operators associated to a smooth morphism. This summarizes recent joint work which started with Claude Sabbah which aimed at first to study the case of modules underlying a mixed twistor *D*-module as well as recent developments in collaboration with Luisa Fiorot.

Maria do Rosário de Pinho (Universidade do Porto)

"Optimal Control: from theory to applications and back"

Abstract: The main aim of this talk is to highlight the synergies between theory and applications in the fascinating area of Optimal Control. First, I give an overview of optimal control problems and its main theoretic challenges of interest to me.

Moving to applications, I present some problems of interest on Epidemiology, Cancer Therapy, Dieting Control and Autonomous Underwater Vehicles showing how such applied problems can trigger the interest and research in different subjects. As far as applications I also highlight the role of numerical methods to compute solutions and I discuss how such method also trigger some serious theoretical questions.

Plenary Speakers

Lucile Vandembroucq (Universidade do Minho)

"Motion planning and topology"

Abstract: Part of the complexity of the motion planning problem for a given mechanical system can be associated with the topology of the configuration space of the system, that is the space of all the possible states of the system. In this talk, I will present a topological invariant, which has been introduced by M. Farber in order to give a measure of this topological complexity and discuss it on some examples.