Jornada IMTech – October 25th 2024

FME – 9:00-14:00

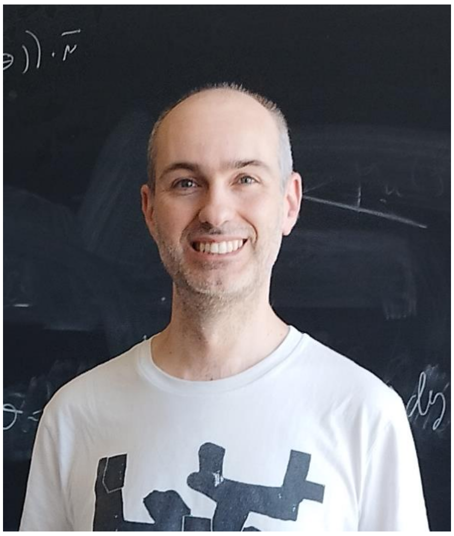
Abstracts for Talks

Daniel Peralta-Salas

Search for optimal domains in plasma physics

It is well known that among all drums of equal area, the circular drum (uniquely) has the lowest voice. The mathematical proof of this fact involves the classical Faber-Krahn inequality for the Dirichlet eigenvalues of the Laplacian, which implies that the ball is the unique optimal domain for the first eigenvalue. An analogous problem arises in plasma physics related to one of the most important vector valued differential operators of first order: the curl. Namely, for a fixed volume, what is the optimal domain for the first positive (or negative) eigenvalue of curl? In this talk I will survey recent results on this problem, which remains wide open.

Brief CV:



Daniel Peralta-Salas is a Senior Scientific Researcher and Chair of the Group on Differential Geometry and Geometric Mechanics at the Institute of Mathematical Sciences (ICMAT) in M adrid, Spain. Since 2016, he has served as a member of the ICMAT board. His research focuses on the connections and interplay between dynamical systems, partial differential equations, and differential geometry, encompassing various topics in fluid mechanics, plasma physics, spectral theory, conservative dynamics, and geometric analysis.

He is a member of the editorial boards of *Revista Matemática Iberoamericana*, *Journal of Dynamics and Differential Equations*, *Qualitative Theory of Dynamical Systems*, and *Geometric Mechanics*. Additionally, he serves on the scientific advisory board of IMTECH (Institute of Mathematics of UPC-Barcelona Tech), the scientific committee of the Royal Mathematical Society of Spain, and is an affiliate member of The International Institute for Sustainability with Knotted Chiral Meta Matter (Hiroshima University, Japan).

Guillem Perarnau

Exploring the maze: A random journey through random graphs

Interconnected systems across biology, sociology, or physics are often represented as graphs, known as complex networks, which exhibit diverse and intricate topologies. To understand these structures, researchers have developed random graph models, providing versatile frameworks for modelling real-world networks. While these models capture network complexity, their sophisticated nature poses challenges for theoretical analysis.

In this talk, we will explore random walks on random graphs, a key area of research influencing algorithms like Google's PageRank. While the theory for undirected graphs is well established, directed graphs, which are common in real-world applications (e.g. World Wide Web, neural networks, social structures), remain less understood. We will discuss recent advances in the area, including results on random stationary measures, mixing properties and the cutoff phenomenon. In particular, we will talk about the `curse of directionality', or how edge directions dramatically increase the time needed to explore a graph. Time permitting, we will present the `power-law hypothesis' which links in-degrees to PageRank.

Brief CV:

Guillem Perarnau completed his bachelor's, master's, and PhD degrees at Universitat Politècnica de Catalunya (UPC), under the supervision of Oriol Serra. From 2013 to 2015, he was a CARP Postdoctoral Fellow at McGill University, where he worked with Bruce Reed and Louigi Addario-Berry. Between 2016 and 2019, he served as a Lecturer in the Combinatorics, Probability, and Algorithms group at the University of Birmingham. Since 2019, he has been an Associate Professor in the GAPCOMB group at UPC. He is also affiliated with CRM, IMTech, and BGSMath.

His primary research interests lie in Probabilistic and Extremal Combinatorics, Random Combinatorial Structures, Discrete Stochastic Processes, and the analysis of Randomized Algorithms.

Currently, he is co-Principal Investigator of the CONTREWA grant, coordinator and Principal Investigator of the Spanish Discrete and Algorithmic Mathematics Network, and a participant in the RandNET MSCA Exchange Programme.

Yolanda Vidal Seguí

Early Fault Detection in Wind Turbines Using Neural Networks with Bayesian Regularization

<u>*Summary:*</u>
In the global effort to achieve net-zero emissions by 2050, wind energy plays a pivotal role. To meet this challenge, improving the reliability and efficiency of wind turbines is essential. It is therefore crucial for the wind industry to transition from corrective and preventive maintenance to predictive maintenance (scheduled as needed based on the asset condition).

This talk explores the use of supervisory control and data acquisition (SCADA) data for wind turbine condition monitoring. Although SCADA systems are primarily designed for normal operation monitoring rather than fault detection, they can offer valuable insights when advanced mathematical modeling and analytical techniques are applied. The challenge arises from the inherent noise and variability in the data, making early fault detection a complex task.

To address these issues, artificial neural networks with Bayesian regularization are proposed. In this approach, the weights of the neural network are treated as random variables with associated probability distributions. Rather than simply minimizing the error, Bayesian regularization balances fitting the data with controlling model complexity. It adjusts the regularization constants based on the data itself, determining how much of the model's complexity is justified. This is elegantly captured through the concept of the effective number of parameters, which reflects how many parameters are actively contributing to model performance, ensuring the neural network architecture is neither over- nor under-complex.

The main contributions of the presented work include: (i) early fault detection is achieved by using only SCADA data, which is already available in all industrial-sized wind turbines (eliminating the need for installing additional sensors); (ii) the proposed method requires only healthy data to be collected, making it applicable to any wind farm, even when no historical fault data is available; (iii) the algorithm works under different and varying operating and environmental conditions; and (iv) the methodology has been validated in a real wind farm consisting of 12 wind turbines, demonstrating its ability to predict faults several months in advance and enabling operators to schedule maintenance proactively, reducing downtime and improving turbine reliability.

<u>*Brief CV:*</u>
Yolanda Vidal holds a degree in Mathematics (1999) and a PhD in Applied Mathematics (2005) from the Universitat Politècnica de Catalunya (UPC), Barcelona, Spain. As an Associate Professor at UPC and an IEEE Senior Member, she actively

engages in multidisciplinary research. Her areas of expertise include mathematical modeling, machine/deep learning, condition monitoring, fault diagnosis and prognosis, and the application of these disciplines in wind turbine technologies. She serves on the Editorial Board of several international journals, including Engineering Applications of AI (Elsevier), Wind Energy (Wiley), Wind Energy Science (Copernicus), and Journal of Vibration and Control (SAGE). Her contributions are reflected in 72 high-impact journal articles, 22 competitive R+D+I projects, 18 book chapters, 10 books, 3 supervised PhD theses, 1 invention patent, an industry collaboration contract, and over 120 conference papers.