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Machine Learning from an Applied Mathematician's Perspective

主讲人：Enrique Zuazua，欧洲科学院院士

专家简介

Enrique Zuazua 教授为欧洲科学院院士、巴斯克科学文学和人文学院荣誉院士，埃尔朗根－纽伦堡大学首位国际学术大使，同时也是动力学、控制、机器学习与数值计算领域的亚历山大·冯·洪堡教授。曾于2006年和2026年两度担任国际数学家大会特邀报告人，并曾任西班牙国家研究计划数学小组首位科学经理（1999-2002）、巴斯克应用数学中心创始科学主任（2008-2012）。他还担任法国 INSMI-CNRS、CERFACS 等多家国际研究机构科学委员会成员，并担任众多应用数学与控制理论领域顶级期刊的主编及编委。

讲座简介

Machine Learning has emerged as one of the most transformative forces in contemporary science and technology. In this lecture, I will discuss Machine Learning through the lens of applied mathematics, highlighting its connections with control theory, partial differential equations, and numerical analysis. The presentation will be organized around three central goals: representation, generalization, and generation.

We begin by revisiting the historical and conceptual links between Machine Learning and systems control (cybernetics). This viewpoint allows us to reinterpret representation and expressivity in deep neural networks in terms of ensemble (or simultaneous) controllability of neural differential equations. Within the same framework, generalization naturally appears as a stability property with respect to perturbations in the data and the model.

Next, we discuss neural-network architectures as tools for numerical approximation. As a guiding example, we consider the classical Dirichlet problem for the Laplace equation, formulated as an energy minimization problem under neural-network constraints. Particular attention will be paid to the lack of convexity and coercivity in the resulting optimization landscape. We will demonstrate how relaxation techniques can restore convexity, albeit at the expense of losing coercivity, and discuss the mathematical implications of this trade-off for both analysis and computation.

Finally, we present a PDE-based perspective on generative diffusion models. Their convergence can be reinterpreted through the asymptotic behavior of Fokker–Planck equations driven by the so-called score field. We will explain how classical tools, such as Li–Yau-type differential inequalities for positive solutions of the heat equation, shed light on the regularization and convergence properties of these models.

We conclude with a discussion of open problems and promising research directions at the interface of control theory, PDEs, numerical analysis, and modern Machine Learning.

承办单位：
数学与统计学院
研究生院

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