Department of Mechanical & Civil Engineering

MCE Seminar Series

"Smart Geomechanics"

Ioannis Stefanou
Professor of Mechanics
UME
ENSTA, IP Paris

Thursday, April 17, 2025
11:00 a.m. PST Seminar

The MCE Seminar will be held in-person in Hall Auditorium, 135 Gates-Thomas. Refreshments will be served at 10:45 a.m. in Housner Lounge on the 2nd Floor of Gates-Thomas.
NOTE: In-person Mechanical and Civil Engineering Lectures are open to all Caltech students/staff/faculty/visitors with a valid Caltech ID.

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Abstract: Geomechanics is a branch of engineering and geosciences that studies the mechanical behavior of the subsurface in response to natural forces and human activities. The subsurface is inherently complex and difficult to observe, making geomechanical problems challenging to analyze both theoretically and computationally. These challenges impact engineering applications, limiting the scope of what is achievable. However, recent advancements in control theory and artificial intelligence (AI) are providing new avenues for studying and managing subsurface behavior. In this talk, I will present recent advances that integrate nonlinear control theory and AI in geomechanics. In particular, I will focus on the behavior of natural and anthropogenic seismic faults, which are responsible for both natural and human-induced seismicity. Novel mathematical results demonstrate how it is possible to stabilize a fault system and induce slow, aseismic slip with a predetermined velocity profile, even in the absence of detailed underground information. In other words, it is mathematically shown that earthquakes can, in theory, be prevented. These theoretical findings are supported by numerical simulations and laboratory-scale analogue experiments. Going further, I will discuss how these insights can be applied to control human-induced seismicity in large reservoirs, potentially unlocking the Earth's remarkable potential for sustainable energy production and underground energy storage. Finally, I will highlight current progress and challenges in smart geomechanics, including optimal placement of actuators and sensors, reduced order modeling and the development of digital twins for computational modeling. These advancements bring us closer to a future where we can actively manage and optimize subsurface behavior in real time.

Bio: Ioannis Stefanou is Professor at ENSTA, member of the Institut Polytechnique de Paris, and researcher at the Institute of Mechanical Sciences and Industrial Applications (IMSIA). He has studied civil engineering, mechanics and applied mathematics at the National Technical University of Athens, and did his PhD at the Laboratory of Geomaterials of the same institution. His main research interests are (geo-)mechanics, dynamics, earthquake control, induced seismicity, control theory, homogenization, machine learning and artificial intelligence. He is the PI of the ERC-StG 2017 project Controlling earthQuakes – CoQuake, of the Connect Talent 2019 project Controlling Extreme EVents – CEEV, awarded by the Pays de la Loire, and of the ERC-CdG 2023 project Preventing human-induced seismicity to fight climate change – INJECT.