Part I: Infrastructure life-cycle planning through sequential decision making optimization under uncertainty and reinforcement learning

Part II: New insights on fragility analysis methods

Abstract:

This talk comprises two distinct parts based on some of the recent research efforts of Dr. Papakonstantinou's group, as explained below. At the end of the talk, a high-level, quick overview of some other research efforts will be presented, with an emphasis on developed methodologies to tackle and quantify stochasticity, as this naturally emerges in a diverse range of engineering problems and applications. Some selected topics will include spatial stochastic variability of reinforced concrete deterioration, stochastic simulation of earthquake ground motions, online inference and system assessment and updating based on monitoring data, efficient quantification of probability of rare events in high-dimensional spaces, and sampling techniques for uncertainty quantification and propagation, among others.

Part I: Infrastructure life-cycle planning through sequential decision making optimization under uncertainty and reinforcement learning

In this first part of the talk, the focus will be on a seamless integration of stochastic models and data for computational sequential decision-making under uncertainty, able to directly and autonomously offer optimal actions to decision-makers/agents. At the core of every engineering problem lies a decision-making quest, either directly or indirectly. Yet, despite significant progress in probabilistic methods and techniques, the actual decision-making process is still largely dependent on the static and rather limited traditional cost-benefit analysis framework, and dedicated rigorous computational methodologies for engineering decisions under uncertainty are practically elusive. As shown in this presentation, challenging sequential decision-making problems in nonstationary dynamic environments can be efficiently formulated along the premises of optimal stochastic control, through Markov Decision Processes (MDPs), Partially Observable Markov Decision Processes (POMDPs), and mixed approaches thereof. However, optimal adaptive planning for large systems with multiple components is computationally hard and severely suffers from the curse of dimensionality. New developments on Deep Reinforcement Learning (DRL) methods and their capacity of addressing this problem are discussed, with emphasis on multi-agent DRL formulations and novel algorithmic schemes developed by Dr. Papakonstantinou and co-workers, specifically tailored to the needs of large systems and able to solve otherwise intractable problems with immense state and action spaces. Numerous ongoing efforts along these lines are shown. At a practical level, this talk with also inform the audience about recent progress in relation to the science of autonomy, as this applies in engineering and beyond.

Part II: New insights on fragility analysis methods

Fragility functions indicate the probability of a system exceeding certain condition/damage states given some appropriate intensity measures. A systematic analysis framework for extended fragility functions that can generally and without any restrictions consider multivariate intensity measures and multiple condition/damage states has been recently proposed by Dr. Papakonstantinou and co-workers, where it is proven, under broad probabilistic assumptions, that the softmax function describes the consistent mathematical form for fragility functions. Accordingly, fragility functions should not be generally described by cumulative distribution functions over the intensity measures space, contrary to what many approaches may currently suggest in the literature. In addition, extended fragility functions completely resolve, under no assumptions and limitations, the issue of crossings of fragility functions, which is a major mathematical inconsistency. In this talk, a critical review of available methodologies for fragility analysis is presented, and a unified viewpoint is provided, based on derived analytical results and mathematical proofs. It is shown that Incremental Dynamic Analysis (IDA) represents a theoretical upper bound of the actual structural fragility, and that the Cloud method provides consistent results with all other examined fragility analysis approaches only under specialized cases. The Multiple Stripes method is also studied as a subcase of the Maximum Likelihood Estimation approach, introduced by Shinozuka and coworkers, which in turn is shown to be a limited subcategory of the extended fragility analysis framework. All relevant aspects, assumptions, eligibility, and relationships between methods are also provided for various settings and numerical examples, starting from the simplest case of one intensity measure and two condition states, to general cases with multidimensional measures and multiple states.

Bio:

Dr. Kostas Papakonstantinou is an Associate Professor of Civil Engineering at Penn State University. He obtained his Civil Engineering Diploma and a M.S. in Structural Engineering from the National Technical University of Athens, and M.S. and Ph.D. degrees in Civil Engineering at the University of California, Irvine. Prior to joining Penn State, he was an Associate Research Scientist at the Department of Civil Engineering and Engineering Mechanics at Columbia University. Dr. Papakonstantinou's work focuses on probabilistic analysis and stochastic mechanics, decision-making under uncertainty, machine learning, optimization/inverse methods, and their integration with computational structural mechanics and engineering applications. Dr. Papakonstantinou has received various awards for his work in these areas, including the CAREER award from the U.S. National Science Foundation.