Cooling the Future: How AI is reshaping heat transfer research

Yoonjin Won

Department of Mechanical and Aerospace Engineering University of California, Irvine

won@uci.edu

Multiphase phenomena are observed in our everyday life in nature and many industrial applications, ranging from dew condensation on insects, water harvesting, electronics cooling, climatology prediction, hydrogen generations, and manufacturing. While the fundamentals of multiphase processes have been studied for over a century, key scientific questions remain regarding the fundamental mechanisms governing complex phenomena. The intricate interplay between the evolution of phase boundaries and mass transport results in nonlinear behavior, where subtle changes in one parameter can have profound and unexpected effects on others. The multimodal, multidimensional, and transient nature of these processes presents challenges for investigation and comprehension. Additionally, interpreting experimental data and predicting multiphase phenomena remain significant challenges. To address these challenges, our research group seeks to integrate cutting-edge computer vision and machine learning strategies. In this talk, Dr. Yoonjin Won introduces a paradigm shift: AI-enabled Thermal Science. By integrating high-speed computer vision with "physics-aware" machine learning, Dr. Won's research group transforms raw visual data of bubble and droplet dynamics into actionable physical insights. She will discuss the development of the vision framework, which autonomously extracts high-fidelity physical descriptors at extreme spatio-temporal resolutions. Dr. Won will demonstrate how these intelligent learning strategies allow us to move beyond traditional observation, enabling the inverse design of predicting complex heat transfer behaviors. This intersection of data science and thermal physics provides a roadmap for the future of sustainable energy systems and advanced electronic cooling.