Risk-Aware AI and Autonomy: From Physics-Informed Learning to Long-Term Safety

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Abstract—Safety and efficiency are fundamental challenges in AI decision making and autonomous control systems, particularly in risk-critical scenarios such as industrial manufacturing and autonomous driving. These systems must make real-time decisions under uncertainty, where incorrect actions can lead to catastrophic failures. This talk presents research that aims to tackle these challenges in two key aspects: 1) efficient online long-term safe control and 2) generalizable offline risk quantification. Specifically, a novel forward invariance concept in probability space is introduced, to form a probabilistic safety certificate that enables effective and efficient safe control for stochastic systems in real time. Then, connections between long-term risk quantities and partial differential equations (PDEs) are drawn to enable physics-informed machine learning techniques for risk quantification of diverse systems and configurations. Theoretical guarantees, extensions, and real-world applications including extreme driving and human robot collaborations are demonstrated. The talk will be concluded by discussing open challenges in generalization, scalability, and human-in-the-loop decision-making, and outline future directions for building reliable, interpretable, and safety-critical AI and autonomy.

Bio—Zhuoyuan (Jacob) Wang is a final-year PhD candidate in Electrical and Computer Engineering at Carnegie Mellon University, advised by Prof. Yorie Nakahira. He obtained his Bachelor of Engineering in Automation at Tsinghua University. His research interests focus on safety-critical decision-making, physics-informed machine learning, stochastic control systems and robotics. He is the recipient of the CIT Dean's Fellowship and the Michel and Kathy Doreau Graduate Fellowship at Carnegie Mellon University.

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