Risk-Aware Design and Control of Socio-Cyber-Physical Systems

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Abstract

Risks in modern complex systems involving crowds of rational decision-makers (DMs) are increasingly sophisticated due to misaligned individual and system objectives, the interdependence between herd behaviors and system operations, and the exploitation of human cognitive vulnerabilities by advanced adversarial threats. Using public health systems as an example of socio-cyber-physical systems, we introduce game-theoretic frameworks to model, analyze, and mitigate systemic risks arising from the coupling of behavior evolution and risk spreading over complex social networks. Information, as the bridge between social dynamics and the physical rules of contagion, emerges as a cost-effective tool for mitigating systemic risk. In the era of misinformation, however, adversarial data and its impact on system performance must also be considered. To address this, we propose an information manipulation game based on a partially observable Markov decision process, where a third party stealthily modifies the observation rules of the process. A stage-wise consistency constraint is introduced to distinguish this framework from traditional data attack models. Finally, we explore the benign use of advanced information technologies to guide crowd decision-making under uncertainty. By introducing the concept of risk preference design within a principal-agent framework, we demonstrate its potential to mitigate moral hazard, enhance risk-sharing, and improve overall system performance.

About the Speaker

Shutian Liu received B.Eng. in Automation from Tsinghua University in 2016, M.S. in Electrical Engineering from Columbia University in 2018, and Ph.D. in Electrical Engineering from New York University in 2024. His research interests lie in the intersection of optimization and game theory, risk modeling, operations research, and network science. Key application domains include socio-cyber-physical systems, AI, human factors, cybersecurity, misinformation, insurance, and public health.

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