Cyber-Physical-Social Intelligence for End-to-End Resilience of Next-Generation Power Systems

WE are pleased to present the 2024 issue of the Journal of Cyber-Physical-Social Intelligence (CPSI), titled "Cyber-Physical-Social Intelligence for End-to-End Resilience of Next-Generation Power Systems." This issue brings together a set of carefully selected regular articles spanning human–robot collaboration, computational stain reduction, brain dynamics identification, and parallel financial systems. Although diverse in application domains, these contributions collectively exemplify the core principles of cyber-physical-social intelligence and reflect the breadth of CPSI research and its relevance to building resilient, interconnected systems across critical infrastructures.

I. SCANNING THE ISSUE

YOU are in My Heart: Enhancing Human-Robot Collaboration-Safety through Human Emotion-Based Perception in Smart Manufacturing Contexts *by HOPE DIAMANTOPOULOS, ZOFIA PRZEDWORSKA, OMAR OBIDAT, JESSE PARRON, AND WEITIAN WANG*

The first article proposes an effective and novel approach that enables human-robot collaboration in smart manufacturing contexts. In particular, the study employs a transfer learning-based method that allows robots to recognize and interpret human emotional states, enabling them to respond appropriately to their human partners during collaborative task execution.

Two-Stage Stain Reduction in Ancient Japanese Manuscripts via Mask-Guided Diffusion Models *by YUYA YOSHIZU, HAYATA KANEKO, RYUTO ISHIBASHI, LIN MENG, AND MINGCONG DENG*

Ancient Japanese manuscripts are invaluable cultural heritage, yet their readability has been severely degraded by stains, bleed-through, and aging effects. The second paper presents an effective stain reduction method to address these challenges and enhance manuscript readability through a mask-guided diffusion-based restoration framework.

The Hidden Markov Model Reveals the Changes in Brain Dynamics among Patients with End-Stage Renal Disease under Different Dialysis Methods *by DANJIE SUN, WEIKAI LI, HUAN YU, XIAOFENG CHEN, AND CHAOYANG ZHANG*

The third paper applies a hidden Markov model to resting-state fMRI data, combined with machine learning techniques and cognitive assessments, to identify distinctive patterns of dynamic brain connectivity. The findings provide potential neuroimaging biomarkers for cognitive impairment in patients with end-stage renal disease under different dialysis treatments.

Parallel Financial Systems: Towards Governable and Sustainable Intelligent Financial Services *by SANGTIAN GUAN, FEI LIN, JUANJUAN LI, JING WANG, AND FEI-YUE WANG*

The last paper proposes a parallel financial systems paradigm based on parallel intelligence and the ACP methodology to address the complexity, uncertainty, and coordination challenges of contemporary financial systems. It introduces a technical architecture integrating AI agents with decentralized technologies such as blockchain, smart contracts, and DAOs, offering a design roadmap for verifiable, privacy-preserving, and interoperable financial intelligence across the project lifecycle.

II. CYBER-PHYSICAL-SOCIAL INTELLIGENCE FOR END-TO-END RESILIENCE OF NEXT-GENERATION POWER SYSTEMS

Uninterrupted access to energy, electrical energy in particular, is a prerequisite for human, societal, and economic development, as well as national security. With ongoing electrification efforts across the transportation, building, manufacturing, and other sectors, any disruption to a nation's electrical system will directly affect the sustainability of its critical infrastructure, threatening public safety and economic stability. However, the elevated cyber and physical risks introduced by increasingly frequent and severe natural and manmade disasters [1-3] continue to challenge highly interconnected cyber-physical power systems, undermining the reliable provision of essential energy services. Thus, building enhanced resilience for next-generation power systems, i.e., adaptivity to maintain operations and service delivery under uncertainty and disruption, is urgently needed, and critical efforts are required.

A. BUILDING CYBER-PHYSICAL-SOCIAL AWARENESS

Power system operators and decision-makers demand enhanced operational awareness capabilities to identify system vulnerabilities and anomalies, enable proactive responses, and ultimately reduce operational risks under deep uncertainty and increasingly complex threat landscapes. Such awareness will provide improved insights into system dynamics, enabling a better understanding of the interwoven cyber-physical-social system operating picture. Achieving this level of operational awareness requires identifying critical interdependencies within and across the cyber, physical, and social domains of power systems, as well as building real-time monitoring and data-assisted analysis of such interdependencies and their evolving impacts on system failures, specifically cascading failures [4], which are among the most important steps towards enhanced resilience.

B. LEVERAGING AI AND DIGITAL TWIN SOLUTIONS

The monitoring, control, and operation of next-generation power systems will be supported by digital communication infrastructures and diverse computer networks, together with experienced operators and decision-makers who may also utilize artificial intelligence (AI)-based support [5-6]. However, the convergence of these systems poses significant challenges to traditional operational analytics, which were not designed in a cohesive manner, and thus without a precise understanding of critical interdependencies and cross-domain failure propagation dynamics [7-8]. In this context, digital twin-based solutions are highly demanded, which can emulate the real-time interactive behavior of cyber-physical-social power systems, enable coordinated simulation, and support the abstraction of critical interdependencies by generating high-fidelity data to capture system spatiotemporal dynamic responses to disruptions. In addition, AI technologies that can analyze, predict, optimize, and coordinate the responsive behaviors of integrated cyber-physical-social systems in real-time represent another important effort towards true resilience, while promoting transparency, accountability, and alignment with societal values during emergencies.

C. ESTABLISHING END-TO-END RESILIENCE

To combat the elevated risks faced by the energy sector during the ongoing infrastructure transition, a suite of federal and state-level efforts has been initiated. For instance, the U.S. Department of Energy (DOE) Office of Cybersecurity, Energy Security, and Emergency Response (CESER) has been working with state energy offices to design, develop, and maintain State Energy Security Plans (SESPs) in response to increasing natural and manmade cyber-physical threats to critical energy infrastructure [9]. However, most of these efforts cannot reach communities, with utility representatives typically sitting in county Office of Emergency Management (OEM) during emergencies. Indeed, local communities, where end-users perceive energy resilience, often lack coordination and response procedures during energy emergencies. Although municipalities often maintain a general emergency response procedure, its robustness relies heavily on resource availability and operational capacity. Challenges, such as staffing shortages and insufficiently trained part-time volunteers that have often cited by local agencies, vary significantly across communities, representing a major vulnerability in the cyber-physical-social energy resilience ecosystem. Therefore, establishing end-to-end energy resilience and coordinating federal, state, and community's preparedness, response, and mitigation efforts in response to energy emergencies should be investigated; meanwhile, the above-mentioned technological advances should be pushed to the community level.

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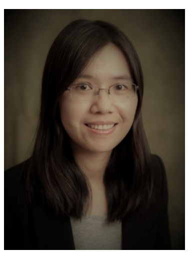

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