Smart Chemical Engineering
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Editorial

Smart Technologies: A Catalyst for Revolutionizing the Future of Chemical Engineering

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1. Introduction

The global wave of smart technologies is driving a profound transformation in reshaping industrial production paradigms. As the foundation of modern industry, chemical engineering underpins critical fields such as energy transition, materials breakthroughs, environmental protection, and biomedicine, while simultaneously facing challenges posed by carbon neutrality goals and industrial upgrading. Against this backdrop, the deep integration of chemical engineering with new-generation information technologies has become essential, propelling it through fundamental shifts: from experience-driven to data-driven methodologies, from decentralized production to intelligent coordination, and from high-energy consumption/high-emissions operations toward green and efficient transformation [1]. Amid contemporary demands for enhanced efficiency, superior performance, greater resilience, and heightened sustainability, traditional chemical process design, optimization, and control paradigms urgently require new intelligent impetus. Accelerated progress in smart technologies such as Artificial Intelligence (AI), big data, the Internet of Things (IoT), and digital twins is comprehensively transforming chemical engineering across all dimensions [2,3]. This revolution is fundamentally restructuring the entire industry chain, from research and development (R&D) to design, production, control, and optimization. Collectively, these innovations are driving the field toward greater efficiency, precision, safety, and sustainability.

The flourishing development of smart driving chemical engineering stems from multifaceted technological support. Widespread deployment of sensor technology and IoT enables reliable real-time acquisition of critical chemical process data, including reaction process, material and composition, separation process, mass and heat transfer, equipment health and performance, safety and environmental, and process control data, and thus establishing a data foundation essential for smart driving chemical engineering. Substantial computing power advancements reinforce this foundation, where high-performance computing (HPC) systems and cloud platforms facilitate effective simulation and solving of complex chemical system models [4], exemplified by kinetic models for catalytic reactions or multiphase flow in reactors. On this basis, continuous algorithm optimization enhances the efficiency and precision of data analysis and predictive modeling. This enables the conversion of raw process data into actionable insights, which drive innovations in chemical engineering frontiers such as green catalytic synthesis, modular process design, and real-time equipment fault diagnosis. Crucially, increasingly strengthened interdisciplinary collaboration gathers diverse expertise, including chemical engineers, data scientists, materials scientists, and environmental specialists. This convergence significantly accelerates the transition of intelligent chemical engineering from fundamental research to practical applications while expanding the frontiers of innovation.

This smart transformation is profoundly reshaping development pathways across all branches of chemical engineering. In advanced materials research, deep integration between high-throughput computing, laboratory robotics, AI predictive models, and autonomous laboratories enables rapid material discovery, reaction mechanism prediction, intelligent design, and efficient synthesis processes, significantly shortening R&D cycles [1,5,6]. In chemical intelligent manufacturing, the synergistic integration of intelligent process control, digital twin, and in-situ monitoring technologies serves as a pivotal driver for enhancing the performance of core chemical processes covering the entire chain from synthesis and processing to molding [7]. This integration effectively improves the precision of synthesis, processing, and molding processes, as well as the consistency and qualification rate of finished products. Within biopharmaceuticals, AI-driven drug molecule screening, protein engineering, and continuous manufacturing (such as CAR-T cell therapies) technologies are redefining drug development efficiency and expanding the frontiers of personalized medicine [8]. Meanwhile, the energy and environmental sector employs smart optimization to enhance renewable energy integration, develop highly active catalysts, and achieve precise control over carbon capture processes, concurrently optimizing emission profiles from industrial operations and fostering synergistic evolution between industrial systems and ecological balance [9]. Across emerging interdisciplinary frontiers, smart technologies are fundamentally reshaping chemical engineering: AI-driven interfaces engineering combined with fully automated experiments is accelerate the functional design of the interface system; real-time data networks supported by the Industrial Internet of Things (IIoT) enable precise control throughout entire production operations; and smart monitoring systems maintain operational safety and equipment efficiency even under extreme high-temperature, high-pressure conditions [10]. Particularly critical is the merger of artificial intelligence with digital twin technology to create high-fidelity virtual process systems, where engineers can test process schemes and rehearse procedures before implementation, substantially reducing trial-and-error costs while elevating safety standards [3].

Amid the rapidly accelerating tide of intelligent transformation in chemical engineering, established journals, while possessing deep expertise in classical chemical engineering theories and applications, have yet to fully align with the development pace of emerging smart technologies and their interdisciplinary integration demands. Firstly, most journals prioritize research on parametric optimization of single processes or fundamental reaction mechanisms. Although considerable knowledge has been accumulated, it remains inadequate for addressing increasingly complex chemical engineering systems and cross-domain integrated solutions. Secondly, the content of journals often focuses on single technological modules or specific experimental outcomes. It lacks in-depth and systematic sorting out and interpretation of the application logic, technical pathways, and system integration methods through which smart technologies run through and reshape the entire chemical industry chain. This makes it difficult for readers to establish an understanding of the overall framework of smart transformation. Meanwhile, some journals pay insufficient attention to the frontier developments in interdisciplinary integration between smart technologies and chemical engineering disciplines. Having yet to track emergent research directions systematically, such a lag creates a gulf between academic achievements and industrial smart upgrading needs, thereby weakening the transformation efficiency of knowledge. Against the backdrop of the industry's smart transformation and in response to these gaps in demand, this journal centers on its core positioning in smart chemical engineering, and commit to building an innovative academic platform that integrates smart technologies, engineering practices, and cutting-edge theories, aggregating frontier research achievements in this field globally, thereby advancing the chemical industry toward an era of sustainable operation, intelligent development, and enhanced efficiency.

2. Aims and Scope

Smart Chemical Engineering (SCE) is dedicated to advancing the innovation of fundamental theories and the development of engineering technology applications in the field of chemical engineering, driven by smart technologies. The journal explores key areas, including cutting-edge process systems design and optimization, advanced materials and technologies, energy-environmental sustainability, and biochemical-pharmaceutical engineering, while emphasizing interdisciplinary collaborations. Particular emphasis is placed on AI-driven innovations in chemical engineering, such as AI-driven reaction/materials design, process optimization and control, digital twin and smart factory, and energy and sustainability. The new journal aims to provide a cutting-edge platform to drive groundbreaking theoretical and technological innovations with transformative potential.

The scope of Smart Chemical Engineering (SCE) encompasses (but is not limited to) the following topics related to chemical engineering:

- Core Chemical Engineering
- Microchemical Engineering
- AI technologies and fundamental theories
- Core applications of AI
- Advanced Materials
- Energy and Sustainability
- Environmental Engineering
- Biochemical and Pharmaceutical Engineering

- Cross-disciplinary Frontiers

3. Outlook

The smart transformation of chemical engineering is not only an inevitable trend in technological development, but also a key pathway to achieving high-quality development of the chemical industry. This journal, driven by smart technologies as its core engine, aims to establish an open and cutting-edge academic exchange platform that fosters the integrated development of fundamental theoretical innovations and engineering technology applications in the chemical engineering domain. It focuses on key directions in the chemical engineering, encompassing both the smart upgrading of traditional core fields, such as AI-driven transport process optimization, reaction engineering and catalysis innovation, and intelligent iteration of separation/purification processes, as well as in-depth exploration of automation and precision control in microchemical engineering, and the smart design/synthesis of advanced functional materials; The journal also tightly integrates breakthroughs in fundamental AI algorithms, including machine learning, deep learning, and reinforcement learning, with their core applications in chemical engineering, deepening into key application breakthroughs such as process control, reaction mechanism prediction, high-throughput experimental screening, and intelligent equipment development; It further prioritizes critical fields including energy and sustainability, environmental engineering, and biochemical/pharmaceutical engineering. Simultaneously, the journal actively advocates for deep interdisciplinary integration and collaborative innovation in frontier directions, paying special attention to cross-cutting fields such as nanotechnology, Industrial IoT (IIoT), digital twin, synthetic biology, and other emerging interdisciplinary frontiers. It aims to strengthen multidisciplinary collaboration, break down field barriers, and catalyze the intersection of knowledge and technologies.

Conflicts of Interest

The authors declare no conflict of interest.

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