

Artificial intelligence in chemical engineering data acquisition and integration

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2.1 Introduction

Engineering processes are being revolutionized by using and integrating artificial intelligence (AI), making them more efficient, automated, and innovative. Chemical engineering, a significantly promoting engineering field, is progressively adopting AI vision to optimize processes, improve safety and security, and reduce manufacturing costs. AI-driven systems are mainly dependent on data availability and quality [1]. These data, collected and monitored using Internet of Things (IoT) networks, advanced sensors, physical measurements, and/or laboratory experiments, should be analyzed and preprocessed before integrating into AI-based systems. In certain cases, the need for large amounts of data coming from different sources is vital for selecting the most suitable AI model for specific tasks. Using AI-based systems in various engineering fields has transformed traditional data collection, acquisition, real-time monitoring, and preprocessing practices. It has given new ideas and possibilities for process optimization and innovations. For example, building energy use is optimized through AI-driven heating, ventilation, and air conditioning (HVAC) systems [2].

In environmental engineering [3], AI-driven systems are employed for various predictive and pollution control strategies for air, water, and soil pollution. AI models utilize massive data collected by sensors, satellites, and other systems, analyze them, and assist in tracking and predicting pollution trends in real time. In mechanical engineering [4], AI models are used in predictive maintenance and design, where machine learning (ML) or deep learning (DL) models can analyze sensor data to predict equipment failure and schedule maintenance to improve uptime and decrease costs. In civil engineering [5], AI helps to improve infrastructure resilience and efficiency for smart city design, traffic control, and structural health management. Electric power systems can be managed at a more advanced level with the help of AI models, which enable the response to demand in real time and optimize grid management and energy utilization [6]. In chemical engineering [7], AI is also used for process optimization and reaction supervision, and even in the supply chain, improving yield and lowering energy usage.

AI helps design aerodynamic models, fuel efficiency optimization, and automatic control systems for aviation [8]. AI was used in biomedical engineering for diagnostics, personalized medicine, and medical imaging, significantly transforming healthcare solutions [9]. In chemical engineering, AI technologies, including hardware advancements and sophisticated algorithms, have led to remarkable progress in organic synthesis, drug discovery, and materials design. These advancements have transformed traditional approaches, allowing for more efficient and effective solutions. However, despite these advancements, the application of AI-driven solutions for analytical purposes has mostly been limited to data quality and availability and data-intensive techniques, especially in image recognition, vibrational spectroscopy, and mass spectrometry [10]. These methods utilize AI's ability to handle large amounts of complex data, yet considerable potential remains for broader application in other analytical fields. Only collecting large datasets is not sufficient [11].

To completely leverage AI's capabilities, well-performing data acquisition, integration, and preprocessing systems are essential [12]. Data silos, inconsistent formats, and real-time processing often arise, making data integration a crucial step

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