

A Comprehensive Review of AI-Enabled Intelligent Instrumentation Systems for Industrial Process Monitoring

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Abstract: *Integration of Artificial Intelligence (AI) with industrial instrumentation is transforming conventional process monitoring into intelligent, adaptive and predictive systems. Traditional instrumentation mainly relies on fixed measurement strategies, predefined alarm thresholds and centralized processing which may be inadequate for complex and dynamic industrial processes. AI-enabled intelligent instrumentation combines smart sensors, data acquisition, industrial communication, edge computing and machine learning techniques to improve monitoring performance and operational reliability. This examines architecture, technologies and applications of AI-enabled instrumentation for industrial process monitoring, with emphasis on intelligent sensing, signal processing, anomaly detection, fault diagnosis, predictive maintenance, sensor fusion and process-state estimation. Role of machine learning, deep learning, explainable AI, edge intelligence and digital twins is also discussed. Major challenges related to data quality, sensor drift, cybersecurity, model interpretability, computational requirements and real-time deployment are identified. Emerging approaches, including physics-informed AI, federated learning, self-calibrating sensors and autonomous instrumentation are also highlighted.*

Keywords: Artificial Intelligence, Intelligent Instrumentation, Smart Sensors, Process Monitoring & Machine Learning