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Energy Consumption Prediction and Optimization in Smart Manufacturing under Industry 4.0

With the rapid advancement of Industry 4.0, the manufacturing sector is undergoing a transformation driven by digitalization, automation, and artificial intelligence (AI). Smart manufacturing, which integrates cyber-physical systems (CPS), the Internet of Things (IoT), and big data analytics, has significantly improved productivity, efficiency, and flexibility in production systems. However, as manufacturing processes become increasingly complex and data-intensive, energy consumption has emerged as a critical concern. Efficient energy management is crucial for both economic and environmental sustainability, as excessive energy use contributes to high operational costs and carbon emissions.

Energy consumption prediction and optimization are key challenges in the era of smart manufacturing. Accurate forecasting enables manufacturers to anticipate energy demands, optimize resource allocation, and reduce waste. Traditional energy management approaches rely on static models and historical data, which often fail to adapt to dynamic production environments. However, Industry 4.0 technologies provide new opportunities to enhance energy efficiency by leveraging real-time data, machine learning (ML) algorithms, and digital twin models. These technologies enable predictive analytics that can identify patterns, detect anomalies, and recommend optimal energy usage strategies in real-time.

This paper explores energy consumption prediction and optimization in smart manufacturing under Industry 4.0. It discusses the role of AI, IoT, and big data in energy management, highlights various predictive modeling techniques, and examines optimization strategies that can reduce energy consumption without compromising productivity. The integration of smart sensors, edge computing, and AI-driven decision-making processes has the potential to revolutionize energy management in industrial settings. By adopting these advanced technologies, manufacturers can achieve energy-efficient operations, lower costs, and contribute to global sustainability goals.