




# Harnessing Machine Learning, Blockchain, and Digital Twin Technology for Advanced Robotics in Manufacturing: Challenges and Future Directions



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**Abstract** This paper digs into robots' revolutionary role in the industrial landscape, highlighting present uses and future trends while addressing ongoing problems. It investigates how machine learning is altering industrial processes, increasing efficiency and production while simultaneously highlighting the challenges of data needs and model interpretability. The evaluation investigates the promise of blockchain technology in enhancing industrial security and transparency, while also recognizing the hazards of possible attacks and smart contract vulnerabilities. The transformational influence of additive manufacturing, particularly 3D printing, is discussed, as well as the constraints connected with printing speed, product quality, and material availability. The study emphasizes the potential of new materials such as bio-based polymers and 2D heterostructures in the advancement of robotic systems. Despite these encouraging achievements, the assessment finds gaps in existing research and suggests future strategies for maximizing the potential of these technologies in the industrial industry.

**Keywords** Machine learning · Blockchain technology · Robotics in manufacturing · Industrial automation · Advanced manufacturing technologies

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