Chapter 14
AI-Driven Adoption and Management Strategies for Advanced Smart Fabrication in Global Manufacturing Enterprises

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ABSTRACT

We propose an AI-driven smart manufacturing framework for real-time monitoring, predictive maintenance, and decision-making in CNC machines. Temperature and vibration sensor data are preprocessed through filtering, normalization, and feature extraction to generate high-quality inputs. Four models ResNet-50 CNN, Stacked Bi-LSTM, Double Deep Q-Network (DDQN), and Random Forest analyze

DOI: 10.4018/979-8-3373-4287-0.ch014

the data from complementary perspectives. ResNet-50 and Random Forest efficiently classify faults and anomalies, while Bi-LSTM captures temporal dependencies to forecast machine states, enabling proactive maintenance. DDQN leverages dynamic sensor feedback to learn adaptive maintenance policies. Evaluations using accuracy, precision, recall, F1-score, and mean absolute error confirm reliability and robustness. The hybrid integration of these models enhances fault detection, prediction, and decision-making, offering a scalable solution for CNC-based smart manufacturing that reduces downtime, improves productivity, lowers costs, and ensures operational safety.

INTRODUCTION

The implementation of artificial intelligence in intelligent manufacturing has expanded exponentially over the last ten years as a response to improved operational effectiveness, downtime reduction, and increased product quality (Tyagi et al., 2024; Lodhi, Gill, & Hussain, 2024; Kini et al., 2022). Machine learning and deep learning patterns have been widely used to detect faults, perform predictive maintenance, and optimize processes in CNC machines and other automated manufacturing processes. These strategies utilize sensor and controller real-time data to support data-driven decision-making so that companies can transition from reactive to proactive approaches to maintenance. Initial research has proven that AI monitoring can detect subtle machine anomalies that are regularly invisible under conventional inspection techniques, leading to better machine reliability and extended life of operation (Sharp et al., 2018; Saxena et al., 2024).

Convolutional neural networks are commonly employed for vibration and temperature data analysis, usually transformed into image or spectrogram formats for spatial and frequency feature extraction. Convolutional neural networks are specifically good at classifying operational conditions and fault detection even when signals have complicated patterns or high noise rates (Altun et al., 2025; Singh et al., 2024). In the same vein, recurrent neural networks, or long short-term memory networks, have been used to model time-series sensor data, learn temporal relationships and accurately predicting future machine state. These models of prediction enable maintenance teams to predict failures prior to their occurrence, minimizing unplanned downtime and related costs (Muruganandam et al., 2023; Bafna et al., 2025).

Deep Q-networks and other reinforcement learning models have also been explored to learn optimal maintenance and operation decisions in dynamic manufacturing environments (Huang et al., 2021; Chowdhury et al., 2024). In interaction with the machine system and learning reward or penalty, these models can generate adaptive maintenance schedules, optimizing both the production performance and machine