

A Integrated Decision Framework for Predictive Maintenance and Dynamic Scheduling in Manufacturing with Rework

Wei-Chih Kuo

Master's Student, Department of Industrial Engineering and Engineering Management
National Tsing Hua University
Hsinchu, Taiwan
wckuo11844555@gmail.com

Kuo-Hao Chang

Distinguished Professor, Department of Industrial Engineering and Engineering Management
National Tsing Hua University
Hsinchu, Taiwan
chang@mx.nthu.edu.tw

Abstract

Rework caused by quality issues frequently occurs in modern manufacturing, disrupting production flow and creating instability in both scheduling and maintenance planning. Such stochastic disturbances make traditional decoupled strategies inadequate, as maintenance decisions often ignore scheduling priorities, while scheduling neglects machine health conditions. To address this challenge, this study develops a simulation optimization framework that smartly integrates predictive maintenance (PdM) and dynamic scheduling using a multi-agent reinforcement learning (MARL) architecture. Four specialized agents—Maintenance, Production, Order Selection, and Coordination—jointly make decisions under uncertainty, guided by Remaining Useful Life (RUL) and Health Index (HI) indicators. The coordination agent dynamically resolves conflicts between maintenance and scheduling actions, ensuring feasible and cost-efficient joint decisions. To further enhance performance, an Expected Improvement Trust-Region Response-Surface Method (EI-TRSM) is incorporated to optimize MARL hyperparameters and balance the trade-off between total cost and on-time delivery rate (OTD). Simulation experiments on multi-stage production lines with stochastic arrivals and rework orders demonstrate that the proposed PdM–Scheduling integration significantly reduces maintenance and tardiness costs, improves delivery reliability, and exhibits robust adaptability compared with heuristic and rule-based baselines.

Keywords

predictive maintenance, dynamic scheduling, reinforcement learning, simulation optimization, response surface method

Biographies

Wei-Chih Kuo is a master's student in the Department of Industrial Engineering and Engineering Management at National Tsing Hua University. He received his bachelor's degree in the Department of Statistics from National Cheng Kung University in 2024. His research interests include statistical analytics, simulation optimization, predictive maintenance, and dynamic scheduling. He is currently a research assistant at the College of Semiconductor Research and the High Entropy Materials Center at National Tsing Hua University, where he applies machine learning and

stochastic optimization algorithms to address parameter tuning problems in semiconductor manufacturing and high-entropy alloy design.

Kuo-Hao Chang is a Professor of Industrial Engineering and Engineering of National Tsing Hua University. He received his PhD in Industrial Engineering from Purdue University in 2008. Professor Chang's research interests include data analytics, applied probability and statistics, and simulation optimization. He was the winner of the 2012 Bonder Scholar Research Award from INFORMS, 2015 IIE Transactions Best Application Paper Award, 2015 K.D. Tocher Medal from The OR Society, 2015 Ta-You Wu Memorial Award from the Ministry of Science and Technology and 2016 Junior Investigators Research Award from the Academia Sinica and 2017 IEEE Transactions on Semiconductor Manufacturing Best Paper Award. He is currently the Associate Editor of several prestigious international journals, including the IEEE Transactions on Automation Science and Engineering, the Asia-Pacific Journal of Operational Research, and the International Journal of Simulation and Process Modeling. Professor Chang and his team has successfully carried out many projects in collaboration with companies, including TSMC, LiteOn, UMC, VisEra, YOMURA, ITRI, III etc. Professor Chang is an active member of INFORMS, IIE and a senior member of IEEE.