UDC 004

ARTIFICIAL INTELLIGENCE IN QUALITY INSPECTION

Tang Qinghua, master's degree student,
Kornienko A., Doctor of Sciences in Physics and Mathematics, professor,
Biziuk A., senior lecturer
Vitebsk State Technological University, Vitebsk, Republic of Belarus

Quality inspection is vital in manufacturing, ensuring products meet standards and customer expectations. Traditional methods – manual sampling or rule-based automation – often lack efficiency, accuracy, and adaptability. AI-powered quality inspection transforms this process using machine learning, computer vision, and data analytics to enable fast, accurate, and scalable defect detection across industries like electronics, automotive, pharmaceuticals, and more.

Core Features of AI in Quality Inspection

– Intelligent Decision-Making: Unlike rigid rule-based systems, AI models such as Convolutional Neural Networks (CNNs) learn from data, identifying complex defect patterns and making autonomous, accurate classifications.

– Comprehensive and Adaptive Inspection: AI enables 100 % real-time inspection on high-speed lines without fatigue, adapting to product and process changes through model retraining.

Key Challenges

– Data Scarcity and Imbalance: Defects are rare, leading to imbalanced datasets that hinder model training. Manual annotation is costly and time-consuming.

– Technical Complexity: Balancing model accuracy with real-time performance, integrating multi-modal sensor data, and handling environmental variability add complexity.

– Industry-Specific Demands: Aerospace requires detecting micro-defects; pharmaceuticals demand regulatory compliance; food production must handle natural variation.

Enabling Technologies

– Deep Learning Models: CNNs (e.g., YOLO, Faster R-CNN) detect and localize defects. GANs generate synthetic defect images to augment limited data. Transfer learning reduces training effort.

– Edge Computing: Enables real-time processing on industrial hardware for speed, privacy, and reliability.

– Digital Twins: Simulate inspection environments to validate AI models before deployment, minimizing risks.

Benefits

– Higher Accuracy & Consistency: AI achieves up to 99.9 % detection rates vs. ~90 % for humans, eliminating subjective errors.

– Operational Efficiency: Real-time, full-line inspection boosts throughput while cutting labor and rework costs by up to 80 %.

– Insight Generation: AI provides actionable data for root cause analysis and predictive quality control.

– Scalability & Adaptability: Easily retrainable for new products or evolving standards.

Challenges & Future Outlook

– Interpretability: Explainable AI (XAI) is needed for safety-critical sectors.

– Continuous Learning: Systems must evolve with changing processes and emerging defects.
– Integration Complexity: Seamless coordination between AI, hardware, and factory IT systems remains a hurdle.
– Future integration with IoT, 5G, and robotics will enable self-correcting production ecosystems, where AI not only detects but also autonomously resolves quality issues.

Conclusion

AI-powered quality inspection marks a shift from reactive to proactive quality management. It enhances product quality, reduces costs, and supports digital transformation, becoming essential in modern smart manufacturing systems.

References

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SUPPLY CHAIN COLLABORATIVE SCHEDULING SYSTEM: INTELLIGENT TRANSFORMATION FROM EFFICIENCY OPTIMIZATION TO VALUE RECONSTRUCTION

Zhang Longlong, master's degree student,
Kazakou V., PhD in Engineering, associate professor, Sokalava H., senior lecturer
Vitebsk State Technological University, Vitebsk, Republic of Belarus

The core attributes of the Supply Chain Collaborative Scheduling System (SCCDS) reflect a profound transformation from single-entity execution to collaborative decision-making, with its core advantages constructed through three key dimensions:

First, cross-entity collaborative decision-making capability. Unlike traditional rule-driven software, SCCDS leverages real-time data collection (e. g., capacity, inventory, order demand) and intelligent algorithm modeling to achieve proactive optimization of multi-stakeholder resources.

Second, multi-dimensional constraint integration capability. The system translates the intertwined constraints in complex supply chain scheduling. It identifies Pareto optimal solutions to reconcile conflicting objectives across these constraints.

Third, dynamic adaptability and resilient architecture. By using IoT to real-time sense environmental changes such as demand fluctuations and supply disruptions, and integrating probabilistic modeling to reserve capacity and inventory buffers, SCCDS enables flexible adjustment of scheduling plans.

The core competency system of the Supply Chain Collaborative Scheduling System (SCCDS) constructs an intelligent scheduling "digital hub" through three dimensions:

First, end-to-end digital twin modeling enables collaborative mapping from local to global levels.