BG Pulse Journal USA

ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg

THE ROLE OF ARTIFICIAL INTELLIGENCE IN MODERN ENGINEERING AND INDUSTRIAL AUTOMATION

Behari G.K

Tecchnical Researcher

Doi: https://doi.org/10.5281/zenodo.22304397

Abstract

Artificial intelligence has become one of the most influential technologies in modern engineering and industrial automation. Its integration into manufacturing systems, robotics, predictive maintenance, quality control, process optimization, and autonomous decision-making has significantly transformed industrial production. The aim of this study was to analyze the role of artificial intelligence in contemporary engineering and evaluate its contribution to automation, efficiency, reliability, and technological development. A literature-based analytical approach was used to examine the applications of machine learning, computer vision, intelligent control systems, digital twins, industrial robotics, and predictive analytics. The analysis shows that artificial intelligence can improve production accuracy, reduce equipment downtime, optimize energy consumption, support real-time decision-making, and enhance product quality. AI-based systems can also process large volumes of industrial data and identify patterns that are difficult to detect through conventional methods. However, successful implementation requires high-quality data, reliable infrastructure, cybersecurity, skilled personnel, and appropriate integration with existing engineering systems. Artificial intelligence should therefore be considered not only as a software technology but also as an important component of intelligent industrial engineering.

Keywords: artificial intelligence, engineering, industrial automation, machine learning, robotics, predictive maintenance, smart manufacturing, intelligent control.

Introduction

Modern industry is increasingly characterized by automation, digitalization, and the integration of intelligent technologies into production systems. Traditional automation is primarily based on predetermined rules, programmable logic controllers, sensors, and control algorithms. Although these systems are highly effective in stable and repetitive environments, they may have limited ability to adapt to complex and changing production conditions.

Artificial intelligence provides new opportunities for industrial systems by enabling machines to analyze data, recognize patterns, predict future events, and make decisions with reduced human intervention.

In engineering, artificial intelligence is now used in mechanical systems, electrical engineering, robotics, manufacturing, energy management, transportation, process control, and maintenance.

One of the most important features of AI-based engineering is its ability to work with large volumes of data generated by industrial sensors and connected machines. Production equipment

continuously generates information about temperature, vibration, pressure, speed, energy consumption, product dimensions, and operating conditions.

Conventional monitoring systems may only indicate whether a predefined threshold has been exceeded. In contrast, machine learning models can analyze complex relationships among multiple variables and identify early signs of abnormal operation.

Artificial intelligence can therefore transform industrial automation from reactive control toward predictive and adaptive management.

The aim of this study was to analyze the principal applications of artificial intelligence in modern engineering and industrial automation and to evaluate its technological advantages and limitations.

Materials and Methods

This study was conducted as a qualitative analytical review of scientific literature related to artificial intelligence, industrial engineering, automation, robotics, machine learning, predictive maintenance, and smart manufacturing.

Scientific publications and engineering studies concerning AI-based industrial systems were examined.

The analysis focused on several major areas, including predictive maintenance, automated quality control, robotic systems, process optimization, intelligent control, energy management, digital twins, and industrial decision-support systems.

Particular attention was given to machine learning, deep learning, computer vision, sensor-based monitoring, and data-driven industrial control.

The collected information was analyzed according to its relevance to engineering efficiency, production reliability, system adaptability, product quality, and operational safety.

Results

The analysis showed that one of the most important applications of artificial intelligence in industry is predictive maintenance.

Traditional maintenance strategies are usually corrective or preventive.

Corrective maintenance is performed after equipment failure, which can lead to unexpected downtime and production losses.

Preventive maintenance is performed at predetermined intervals, but this may result in unnecessary replacement of components that are still functional.

AI-based predictive maintenance uses operational data to estimate the condition of machinery and predict possible failures before they occur.

Sensors installed on industrial equipment can continuously measure vibration, temperature, acoustic signals, electrical current, rotational speed, and other parameters.

Machine learning algorithms can analyze these data and identify patterns associated with abnormal wear or mechanical degradation.

This allows maintenance teams to plan repairs at more appropriate times and reduce unplanned downtime.

Artificial intelligence also has an important role in industrial quality control.

Computer vision systems can automatically inspect products during production.

Cameras and image-processing algorithms can detect cracks, incorrect dimensions, surface defects, assembly errors, and other abnormalities.

Deep learning systems can be trained using large image datasets to recognize defects with high consistency.

This approach can reduce dependence on manual visual inspection and increase production speed.

Another major area is robotics.

Traditional industrial robots usually perform fixed repetitive movements.

AI-enhanced robots can process sensory information, adapt to changing conditions, and perform more complex tasks.

Machine vision enables robots to identify objects and determine their position and orientation.

This is useful in assembly, packaging, sorting, welding, material handling, and warehouse automation.

Collaborative robots can also operate in closer interaction with human workers when appropriate safety systems are implemented.

Artificial intelligence can improve process optimization.

Industrial processes often involve many interconnected parameters.

For example, product quality may depend simultaneously on temperature, pressure, speed, material composition, and processing time.

Machine learning models can identify relationships among these variables and recommend settings that improve productivity or reduce waste.

AI-based optimization is also useful in chemical processing, metallurgy, energy production, and manufacturing.

Energy management represents another important application.

Industrial enterprises consume large amounts of electricity and thermal energy.

Artificial intelligence can analyze energy consumption patterns and identify periods or processes associated with unnecessary losses.

Intelligent systems can then adjust equipment operation according to production demand.

This may contribute to reduced energy consumption and improved environmental performance.

Artificial intelligence is also increasingly integrated with digital twin technologies.

A digital twin is a virtual representation of a physical machine, production line, or industrial system.

Real-time sensor data can be transmitted from physical equipment to its digital model.

AI algorithms can analyze the digital twin to predict performance, evaluate operating scenarios, and identify potential failures.

This creates opportunities for testing changes before they are implemented in the real system.

Industrial decision support is another significant area.

Modern factories generate large amounts of data that may be difficult for engineers to interpret manually.

AI-based systems can analyze this information and provide recommendations regarding production scheduling, maintenance, inventory, energy use, and process control.

The results therefore demonstrate that artificial intelligence can influence nearly every stage of industrial production.

Discussion

The findings indicate that artificial intelligence is transforming the principles of industrial automation.

Traditional automation follows predefined instructions.

AI-based automation can incorporate learning, prediction, classification, and adaptive decision-making.

This distinction is especially important in complex industrial environments where operating conditions change over time.

Predictive maintenance is a clear example.

Instead of waiting for equipment to fail or replacing components according to fixed schedules, AI systems can estimate the actual technical condition of machinery.

This may improve equipment reliability and reduce maintenance costs.

Computer vision also demonstrates the practical value of artificial intelligence.

Visual inspection tasks can be repetitive and affected by human fatigue.

Automated image analysis can provide continuous inspection and consistent evaluation.

However, the performance of such systems depends strongly on training data.

If the dataset does not represent all relevant defect types, the system may fail to recognize unusual abnormalities.

Data quality is therefore one of the most important requirements for industrial AI.

Incorrect sensor measurements, missing values, insufficient historical data, and inconsistent labeling can reduce model reliability.

Another important challenge is cybersecurity.

Industrial AI systems are often connected to communication networks, cloud platforms, sensors, and production equipment.

This connectivity increases efficiency but also creates additional cybersecurity risks.

Unauthorized access or manipulation of industrial data could affect production decisions or equipment operation.

Therefore, cybersecurity must be integrated into the design of intelligent industrial systems.

Human expertise also remains essential.

Artificial intelligence should not be viewed as a complete replacement for engineers.

AI systems can process data and identify patterns, but engineers are required to define technical objectives, evaluate system behavior, interpret results, and ensure safe operation.

The most effective model is therefore human–machine cooperation.

Engineers provide domain knowledge and responsibility, while AI provides computational support and rapid data analysis.

Another challenge is explainability.

Some advanced machine learning models can produce highly accurate predictions but may not clearly explain how a result was obtained.

In safety-critical engineering, this can be problematic.

Engineers often need to understand why a system recommends a particular action.

Therefore, explainable artificial intelligence is becoming increasingly important in industrial applications.

Economic factors must also be considered.

Implementation of AI may require sensors, data infrastructure, computing resources, software, integration, and staff training.

Large enterprises may be able to introduce advanced systems more rapidly than small organizations.

However, scalable cloud-based and modular solutions may reduce these barriers over time.

The long-term significance of artificial intelligence lies in the development of autonomous and adaptive manufacturing systems.

Factories of the future may increasingly use interconnected machines capable of monitoring their own condition, adjusting production parameters, coordinating logistics, and optimizing resource consumption.

Nevertheless, such systems require strong engineering standards, safety controls, human oversight, and reliable data governance.

Conclusion

Artificial intelligence has become an important component of modern engineering and industrial automation.

Its major applications include predictive maintenance, computer-based quality control, intelligent robotics, process optimization, energy management, digital twins, and industrial decision support.

AI-based systems can improve production efficiency, reduce equipment downtime, enhance product quality, support real-time monitoring, and improve the adaptability of industrial processes.

Machine learning and sensor analytics allow engineers to move from reactive maintenance toward predictive management.

Computer vision can automate inspection, while intelligent robotics can perform increasingly flexible manufacturing tasks.

Despite these advantages, successful implementation requires reliable industrial data, cybersecurity, technical infrastructure, trained personnel, and careful integration with existing engineering systems.

Artificial intelligence should therefore be considered a complementary engineering technology that strengthens, rather than eliminates, human expertise.

Overall, the integration of artificial intelligence with automation, robotics, sensing systems, and digital manufacturing technologies is likely to play a major role in the continued development of intelligent and sustainable industrial production.

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