Volume 1 No 12, 2025
Journal of Global Research in Multidisciplinary Studies (JGRMS)
Review Paper
Available online at https://saanvipublications.com/journals/index.php/jgrms/index

AI-Powered Industrial Robots in Smart Factories: A Survey of Applications Challenges and Future Trends

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***Abstract*—The integration of Artificial Intelligence (AI) with industrial robotics is driving the evolution of smart factories, creating environments that are intelligent, adaptive, and highly efficient. By combining machine learning, computer vision, and real-time decision-making with advanced robotics, industries are achieving greater flexibility, precision, and productivity. Smart factories leverage enabling technologies such as Industrial Internet of Things (IIoT), cloud/edge computing, and collaborative robots to enhance workflow optimization, predictive maintenance, and quality assurance. This survey explores the applications of AI-powered industrial robots, including autonomous material handling, adaptive manufacturing, defect detection, and micro-manufacturing, which contribute significantly to cost efficiency and operational reliability. It further highlights the challenges hindering adoption, such as high implementation costs, integration with legacy systems, safety concerns, and the requirement for skilled expertise. The paper also reviews existing literature to provide insights into technological advances, industrial impact, and global adoption trends. Findings emphasize that AI-powered robotics not only enhances productivity and sustainability but also paves the way for Industry 4.0 transformation. Future directions focus on interdisciplinary collaboration, ethical AI deployment, and advanced cognitive robotic systems for sustainable and resilient manufacturing ecosystems.**

Keywords—Smart factories, AI-powered, industrial robots, industrial automation, machine learning, collaborative robots, intelligent manufacturing.

I. INTRODUCTION

Smart factories represent the foundation of Industry 4.0, combining cyber-physical systems, digital connectivity, and intelligent automation to create adaptive and data-driven production environments. Unlike traditional factories, which rely on rigid processes and manual oversight, smart factories emphasize flexibility, horizontal and vertical integration, and end-to-end digital workflows across the entire value chain [1]. These environments involve real communication time, automated process and minimum human interventions, and a huge spectrum data analysis to identify patterns, optimize resources, and model process. There are still obstacles to these benefits being fully realized, however, which include poor or incomplete data. Smart factories cite increased efficiency and cuts on wastage, as well as sustainable and resilient manufacturing environments that are made possible by connectivity and intelligent decision-making processes [2].

Industrial robotics has also witnessed an incredible development whereby the industry that utilizes rigidity programmed machines has shifted into intelligent robots whose functions are supported by AI. The older robots were built to fulfill single-purpose or repetitive tasks, but nowadays [3], with the development of artificial intelligence (AI), machine learning (ML) [4] and sensor integration, they are capable of operating independently, adapting to different environments and most importantly, taking exacting actions. The trend has been spurred by the increased demand for automation across different industries globally, including automobile, electronics, health and logistics, which help to cut operational costs and increase productivity and adaptability [5]. Collaborative robots (cobots) form an important breakthrough in this area as they are equipped with proximity sensors, force-restraining and price-conscious intent recognition systems that can safeguard close human-robot interaction on factory floors.

The implementation of AI-driven industrial robots in smart factories generates a new model of smart, networked, agile production [6]. Smart factories, through integrating robotics with Industrial Internet of Things (IIoT), cloud and edge computing, and predictive analytics, can optimize workflow in real-time, predictively maintain equipment, and collaborate with people in new ways; and more [7][8]. Robots with computer vision can now inspect quality in real time, and reinforcement learning can enable such robots to learn new tasks relatively quickly, without requiring major reprogramming. These functions result in quantifiable advantages such as increased productivity, enhanced flexibility, enhanced safety and huge cost savings. Meanwhile, issues such as prohibitive implementation costs, system interoperability and the requirement of skilled expertise must be overcome to achieve their full potential.

The paper reviews the role of industrial robots powered by AI in smart factories, including enabling technologies, applications, challenges, and emerging trends, as well as a literature review to help gain insight into the creation of sustainable, efficient, and human-friendly manufacturing facilities.

A. Structure of the paper

The paper has the following structure: Section II examines smart factory ideas and technologies. Section III talks about AI in robotics and its categories, and integration of the system. Section IV highlights applications, challenges, and future trends. Section V presents the literature review. Section VI provides the conclusion and outlines potential future research directions.

II. Smart Factories: Concepts and Technologies

Smart factories are advanced manufacturing systems integrating AI, IoT, robotics, and cloud-edge computing to enable flexible, adaptive, and efficient production. They prioritize efficiency, quality, and adaptability, featuring modular, reconfigurable systems, knowledge sharing, and cross-boundary collaboration. Evolving from manual workshops to Industry 4.0, smart factories leverage intelligent robots for precision tasks, predictive maintenance, and real-time quality control, resulting in improved productivity, cost reduction, and sustainable operations.

A. Characteristics of the Smart Factories

A Smart Factory is a way to make things that offer production methods that are so adaptable and flexible that they can solve problems that come up in a world where things are getting more complicated all the time [9]. Automation, which may be defined as a system that combines software, hardware, and mechanics, is one possible component of this unique solution. If implemented properly, it should optimize industrial processes, cutting down on wasteful labor and resources [10][11]. Or, one may look at it from the angle of a partnership between several non-profit and for-profit organizations, where the brilliance is in the formation of a dynamic organization. Smart factories exhibit several key characteristics that distinguish them from traditional manufacturing systems:

- **Functionality-focused:** Prioritizes operational goals such as efficiency, adaptability, and quality over specific technologies
- **Flexible manufacturing:** Capable of rapid adaptation to changes in products, production volumes, and customer requirements.
- **Modular and platform-based:** Employs modular designs and platforms to reduce costs, enhance scalability, and simplify system reconfiguration.
- **Cross-boundary collaboration:** Encourages cooperation across cultural, geographical, and disciplinary boundaries to foster innovation.
- **Knowledge sharing:** Integrates information and expertise across teams and partners to improve problem-solving.
- **Reconfigurable systems:** A production line and other machinery can easily be changed to support new production or processing.
- **Agile and lean operations:** Supplies a combination of efficacy and sharp responsiveness to adapt to the ever-changing market condition.
- **Adaptive production:** Supports transformation of operations in response to emerging technologies or market trends.

B. Enabling Technologies

The development of AI-powered industrial robots in smart factories is underpinned by a set of enabling technologies that facilitate autonomous operation, real-time decision-making, and seamless integration across manufacturing processes. These technologies collectively enhance efficiency, flexibility, and adaptability within modern production environments as shown in the Fig. 1.

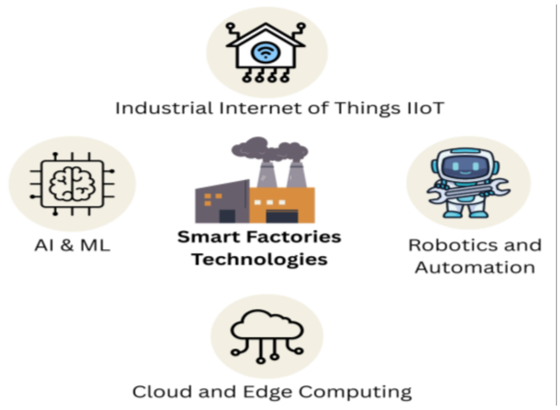

Fig. 1. Smart Factory enabling Technologies

1) Artificial Intelligence and Machine Learning:

Intelligent industrial robotics is centered around AI and ML [12][13]. Using AI techniques, the robots are able to see their environment, take context-dependent decisions, as well as optimize how they perform the task. Computer vision enables robots to detect things, track quality and navigate in complex environments and reinforcement-based learning and deep learning enhance the ability to adapt to the task over time.

2) Industrial Internet of Things (IIoT)

IIoT has given the industrial sector the data infrastructure that smart factories require. Sensors placed on the robotic systems and equipment seize real-time working data and send it through IIoT networks in order to analyze it. This unlocks anomaly detection, process optimization and multi-robot coordination [14].

3) Advanced Robotics and Automation

The contemporary industrial robot is mobile, exerting dexterity in end-effectors and collaborative abilities. There are collaborative robots (cobots) that are safe to operate with humans, and which can complete high-precision or monotone tasks. Integration with automated guided, autonomous mobile robots provides material handling, production synchronization and intra-factory logistics.

4) Cloud and Edge Computing

Cloud and edge computing develops the computing power necessary in the AI-ready robotic systems. Edge computing has been described as processing that employs the capabilities of edge devices and, when powered by cloud analytics and model training, enables low-latency responses to critical operations. Hybrid edge-cloud architectures enable distributed intelligence and robots can collaborate and learn to achieve a better overall performance.

These technologies together comprise autonomous, adaptive and intelligent manufacturing and more advancements are likely to improve even further on the efficiency, safety and flexibility of smart factories.

C. Evolution of Manufacturing Systems and their Industrial Impact

Historical developments of manufacturing systems have gone through manual workshops to automatic production lines and to intelligent smart factories. Early manufacturing depended more on human labor and other craftsmanship meaning that the scale of production, speed, and precision were limited. The evolution of efficiency and output through the introduction of mechanical factories and assembly lines during the Industrial Revolution was dramatic, but the improvements were inflexible in response to needs and wants with limited animal power available to support the system decisions made in the factory.

The advent of CIM, FMS, and automation and modularity in the late 20th century made more precision, customization, and control possible. Industry 4.0, marking the pinnacle of this transition, is defined by interconnected cyber-physical systems [15] gadgets enabled by the IoT, big data analytics, and AI. In modern smart factories, AI-powered industrial robots perform tasks including precision assembly, predictive maintenance, and real-time quality control. These robots are capable of learning from operational data and adapting to dynamic environments, thereby increasing production flexibility and responsiveness. The industrial impact of these developments includes the following key benefits:

- **Efficiency gains:** Optimization of workflows, reduction of downtime, and increased production speed.
- **Flexibility:** Capability to manage product variations and rapidly respond to market changes.
- **Productivity improvements:** Higher output with consistent quality and minimized human errors.
- **Cost reduction:** Lower labor costs, minimized waste, and predictive maintenance decrease operational expenses.
- **Sustainability:** Optimized energy and material usage, reducing environmental impact.

The transition from manual to intelligent manufacturing systems has transformed production into a data-driven, adaptive, and highly efficient process. AI-powered industrial robots are central to this transformation, providing significant economic, operational, and environmental benefits.

III. Artificial Intelligence in Advanced Industrial Robotics

Artificial intelligence (AI) is revolutionizing industrial robotics and smart manufacturing by enabling robots to perform complex, adaptive tasks. Machine learning, computer vision, and reinforcement learning are some of the artificial intelligence technologies that modern factories use to power the many different kinds of robots used in manufacturing. The concept of smart industrial robots integrates hardware, software, sensors, control systems, and connectivity to achieve autonomous operation and seamless human–robot collaboration. These advancements enhance productivity, precision, flexibility, safety, and adaptability, solidifying AI-powered robotics as a cornerstone of Industry 4.0.

A. *Classification of Industrial Robots*

Modern smart factories couldn't function without industrial robots, which provide precision, velocity, and flexibility in spades. Articulated robots, SCARA robots, cobots, and AMRs are some of the most common types of industrial robots used for process simplification. These robots not only support adaptive, Industry 4.0-driven production but also enhance productivity and enable effective human–robot collaboration.

1) *Articulated Robots*

These robots feature multiple rotary joints (typically 6 or more degrees of freedom), offering significant flexibility in movement. They are widely used for tasks like welding, handling heavy loads, and flexibility in industrial environments. This flexibility allows them to perform complex tasks in industrial environments, such as welding, handling heavy loads, palletizing, and machine tending. Their versatility makes them ideal for applications requiring a wide range of motion and precision.

2) *SCARA Robots*

The Selective Compliance Assembly Robot Arms, or SCARAs, are robots designed to be rigid in the vertical axis but flexible in the X-Y plane [16]. They are therefore perfect for high-speed, high-precision assembly jobs like putting pins in or arranging components in confined areas. This design makes them exceptionally suitable for high-speed, high-precision assembly tasks, such as inserting pins or arranging components in confined spaces, as displayed in Fig. 2. SCARAs are widely employed in industries like electronics, automotive, and pharmaceuticals, where speed and accuracy are critical.

Fig. 2. SCARA Robot [17]

3) *Collaborative Robots (Cobots)*

Cobots are designed to operate securely next to people in barrier-free shared workspaces [18]. They are particularly useful in small-batch or SME environments since they are adaptable, simple to program, and perfect for jobs like assembling and packing. Cobots are commonly used for assembly, packing, and other repetitive tasks, enabling efficient human–robot cooperation without compromising safety.

4) *Autonomous Mobile Robots (AMRs)*

AMRs are mobile, intelligent robots without infrastructure that can move and move materials on their own in intelligent warehouses or factories [19]. They improve intralogistics efficiency and layout flexibility, which are essential to contemporary production flows. *AMRs enhance layout flexibility and enable seamless production flows, making them an essential component of modern, automated manufacturing systems.*

5) *Delta Robots*

Delta robots are parallel-link robots characterized by their lightweight arms, high-speed movement, and exceptional precision, making them ideal for tasks that require rapid, repetitive motions. Unlike articulated robots, Delta robots maintain high stiffness and accuracy while operating at very high speeds, which makes them particularly suitable for pick-and-place, packaging, sorting, and assembly operations in industries.

B. *AI Technologies in Robotics*

Innovations in robotics have boosted present and future technological capabilities through the incorporation of features that improve the efficiency of many fields and the innovative use of ML in many different applications [20], a few of which are covered in Fig. 3.

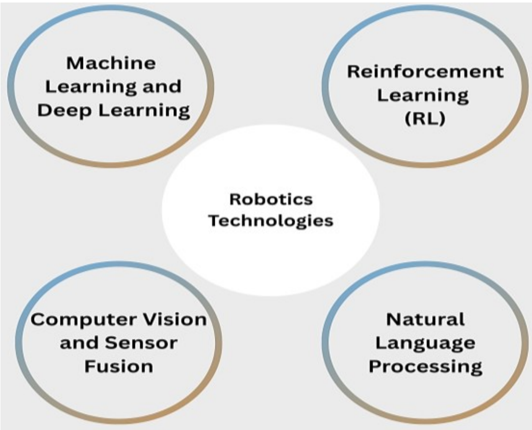

Fig. 3. Robotics Technologies

1) *Machine Learning and Deep Learning*

Robots may learn patterns from data to become autonomous and make decisions using ML [21]. Multi-layer neural networks are used in DL, a subfield of ML [22], to process complicated inputs such as sensor or visual data. These methods enable robots to adapt to new situations by powering activities like sensing, grasping, and navigation.

2) *Computer Vision and Sensor Fusion*

Robots can analyze visual input using computer vision, from basic object recognition to sophisticated scene comprehension [23]. Utilizing a combination of many sensor inputs (such as cameras, LiDAR, IMUs, etc.), sensor fusion is able to generate a more thorough and precise representation of the environment. Examples include the use of time-of-flight sensors in conjunction with visual tracking to improve control and localization.

3) *Natural Language Processing in Robotics*

Robots can now comprehend and produce human language using Natural Language Processing (NLP), which makes communication more natural [24]. Applications that greatly enhance usability in the healthcare, service, and assistive sectors include speech-based navigation, emotional recognition, and context-aware replies.

4) *Reinforcement Learning (RL) for Robotic Control*

RL trains robots to learn actions via trial and error. This makes it possible for them to adjust to changing and unpredictable environments, which is perfect for activities like gripping, moving, and navigating [25]. Direct learning from high-dimensional inputs, such as photographs, is further made possible by deep reinforcement learning. The sim-to-real distance and sampling inefficiency are obstacles.

C. *Smart Industrial Robot Concept and Integration*

The concept of smart industrial robots is centered on the *see–think–act* principle, which integrates perception, adaptive planning, and motion execution into a closed-loop system. This architecture enables robots to sense their environment, analyze information, and perform actions with precision. This is essential to self-reliance, flexibility, and cooperation in smart factories. The smart industrial robot concept combines sensing, information extraction, decision-making, and motion control, enabled by continuous interaction with the environment and learning (as shown in Fig. 4).

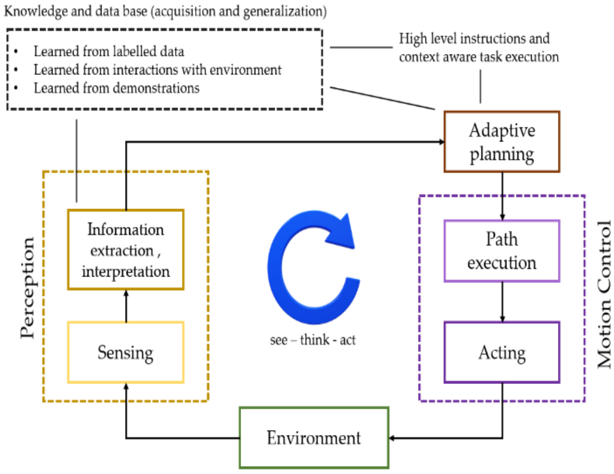

Fig. 4. Smart industrial robot concept [26]

The essential elements of the smart industrial robot can be discussed in four major points:

1) *Hardware and Software Frameworks*

Smart robots are a mix of physical items including sensors, actuators and robotic arms together with AI-based software platforms. These frameworks can support real-time perception and learning and adaptive decision-making to industrial contexts.

2) *Control Systems*

Controllers perform the role of a bridge between actuation and sensing. They receive sensor information, compute, and provide commands, and bring about feedback loops to ensure accuracy, stability and adaptability to change in unpredictable, high-change situations.

3) *Sensors and Perception*

Vision, tactile and proximity sensors are used to acquire contextual information of the workspace. Such data is interpreted by AI-based models to perform object recognition, detect anomalies, and optimize tasks.

4) *Connectivity and Factory Integration*

Industrial robots utilize industrial protocols in communication, including OPC UA, EtherCAT, and 5G-based IoT. This connectivity ensures seamless data exchange and integration with other machines and management systems in smart factories.

D. *Advantages of AI-powered robots*

AI-powered robots offer significant benefits over traditional automation, enhancing efficiency, precision, and adaptability across industrial operations:

1) *Increased Productivity and Efficiency*

AI and robotics substantially boost industrial production and efficiency. The use of AI-powered robots indicates that the robots are not only ready to work but also excel in repetitive and heavy tasks faster than humans. This in turn leads to faster production cycles, less idle time and more output. For example, AI-driven robots can operate complex assembly lines, control material flow, and supervise stock management systems with little human intervention.

2) Flexibility and Decreased Product Variability

The production degree and performance of the product is much advanced because of robots and artificial intelligence. Robots are designed for accuracy in performing various tasks, hence the chances of errors and variation in the final product are virtually eliminated [27]. Al systems can self-adjust and control the processes to make sure the final output complies with specific as well as stringent quality criteria. Such accuracy level is particularly beneficial in industries such as electronics and automobile.

3) Augmented Safety

Robotics and Al contribute to job site safety enhancement. Difficult tasks such as working in extreme temperature zones, processing of toxic substances, and performing delicate operations in dangerous areas may be done by robots. By doing so, the rate of accidents and health-related problems among workers is lowered. Al systems could install sensor and video information in order to recognize and solve safety concerns for further steps to be taken. This makes it possible to anticipate measures that would create safer environments.

4) Versatility and Adaptability

Production processes can be highly adaptable and nimble help from Artificial Intelligence and robotics technologies. Today's robots can be adapted in a flexible and reconfigurable manner as well as to some degree of programmability in a restricted range of tasks, which is a solution to quickly adapt to changing production needs. Particularly for purposes beyond line changes but also for clarifications, this flexibility is, in fact, most useful. Al systems could also be adapted to utilize live input to adjust supply chains and others processes in real time [28].

IV. AI-ENABLED INDUSTRIAL ROBOTICS: APPLICATIONS, CHALLENGES, AND FUTURE TRENDS

AI-enabled industrial robots are revolutionizing modern manufacturing, logistics, and production by combining traditional robotics with intelligence, perception, and adaptability. These robots are capable of understanding their environment, making decisions, and interacting safely with humans and machinery, which significantly improves operational efficiency, productivity, and safety.

A. Applications

AI-enabled industrial robots are transforming manufacturing by combining intelligence, adaptability, and precision. Key applications include:

- **Adaptive Manufacturing Robots:** These robots are perfect for flexible or small-batch manufacturing because they can handle products of varying forms, sizes, or weights without reprogramming because they dynamically adjust their movements based on real-time production data.
- **Autonomous Material Handling:** Robots transport raw materials, finished goods, and parts within warehouses or factories using sensors and AI-based navigation to optimize routes, avoid obstacles, and coordinate with other robots, enhancing speed and accuracy.
- **Inspection and Quality Control Robots:** These robots are outfitted with cameras and sensors to identify any defects, imperfections on the surface, or any misalignment in real time, keep the product at a consistent quality level, and minimize wastage in manufacturing process.
- **Predictive Maintenance Robots:** Robots have the ability to detect when machines are in less than perfect shape, before it is too late through sensors and analytics, enabling them to put machines down to self-heal proactively, reducing unplanned machine downtime and equipment life expectancy in the process.
- **Precision and Micro-Manufacturing Robots:** Robots are used in fields, such as electronics, pharmaceuticals, and semiconductors [29] to manipulate delicate or small parts in settings such places with high levels of precision, increasing repeatability and quality of the product and overall manufacturing dependability.

B. Challenges

Technological automation through AI-enabled robots has a number of barriers to adoption. Major challenges include:

- **High Implementation Costs:** Small and medium-sized businesses may find it challenging to invest in industrial robots, particularly ones with artificial intelligence capabilities, due to the high upfront costs associated with the necessary hardware, sensors, and integration into their production lines.
- **Complex Integration with Existing Systems:** Many factories still use older machines and control systems. Integrating new robotic solutions with legacy equipment can be technically challenging and often requires extensive reconfiguration or upgrades.
- **Safety and Human-Robot Interaction:** Despite AI-enabled sensing and control, ensuring safe collaboration with humans remains a major concern. Robots must reliably detect human presence, avoid collisions, and respond appropriately to unexpected actions.
- **Maintenance and Technical Expertise Requirements:** Industrial robots require ongoing maintenance and skilled personnel to operate, program, and troubleshoot them. A shortage of trained robotics engineers can limit their deployment and efficiency [30].

C. Future Trends

The future of AI-enhanced robotics in smart factories promises significant advancements, with robots gaining advanced cognitive abilities that allow them to analyze complex data, make nuanced decisions, and adapt seamlessly to dynamic production environments. To reduce latency and improve responsiveness, edge computing essential by allowing on-site real-time data processing. When used in tandem with human operators, collaborative robots (cobots) increase efficiency, adaptability, and production while handling increasingly complex jobs [31].

The advanced robotic systems cannot be developed without interdisciplinary collaboration. Multidisciplinary teams of roboticists, machine learning researchers, engineers, ethics and human factors experts, assembled to develop intelligent, socially responsible and end-user friendly solutions. Strong regulatory frameworks communicated by organizations secure ethical use of AI, safety, and ability to evolve with changes to technology as the AI-enhanced robots begin to exist within the context of smart factories.

V. LITERATURE OF REVIEW

AI is the most important facilitator in the deployment of smart factories as it enables the technology to automate industry and improve efficiency of operations besides making intelligent decisions. Recent research explored different areas of robotics using AI, such as uses and applications of such robots, challenges and prospects in the future.

Pandy et al. (2025) investigate the incorporation of AI into robotics, with a particular emphasis on its potential uses in manufacturing and healthcare. Artificial intelligence is improving operational workflows and allowing robots to make independent decisions, among other ways it is changing robots' interactions with people and their surroundings. The research suggests a system for integrating AI-driven robots with little disruption, with an emphasis on learning algorithms, sensor technology, and human-robot cooperation. Problems arise when there are limited resources, ethical considerations, and problems with scaling. Robots driven by artificial intelligence have proven to be an essential component of contemporary automation, thanks to their remarkable increases in accuracy, efficiency, and decision-making capacity [32].

Daely et al. (2025) study presented a framework for the provisioning of pickup and delivery (P&D) tasks and the routing of vehicles for use by carrier robots in a manufacturing setting, with edge servers acting as a go-between for the robots and the workstations from which the requests for these tasks originate. With minimal trip distance and no violations of specified limits, the carrier robots are to collect and transport each allocated load from and to specified locations. The main server uses edge servers to communicate with the delivery robots, and the robots in turn help the main server determine which robot is most suited to complete each incoming task request and alter their routes accordingly. A discrete bio-inspired algorithm is suggested to address the issue of pickup and delivery for every robot, which is modelled after the Dial-a-Ride Problem. Edge servers and carrier robots have their service loads taken into consideration when tasks are allocated to them. The results of the simulations demonstrate that the suggested framework may effectively optimize the smart factory's pickup and delivery procedure [33].

Igbokwe Benson Ikechukwu (2024) study was carried out in Anambra State to assess the effectiveness of robots driven by artificial intelligence in the logistics and manufacturing sectors. Two hundred employees in managerial and executive roles participated in the poll, which used a comparative survey approach. A reliability coefficient of 0.83 was determined after validating the AIPRHEQ questionnaire. While people possess cognitive abilities and situational awareness, the results demonstrated that AI-powered robots performed better at logistics tasks like selecting alternate routes. AI robots have enhanced productivity and reduced operational costs by performing repetitive jobs with remarkable speed, accuracy, and efficiency. According to the study's authors, businesses should tailor their use of AI and robot automation systems to their specific logistical and production needs [34].

Khalid (2024) the exploration of AI in robotics has marked a profound change in manufacturing. Using AI algorithms, autonomous robots become the drivers of manufacturing systems, making them more adaptable, highly productive and cost-effective. Due to this, these robots have the potential to revolutionize industries such as automotive and electronics by being able to do more complicated tasks, adapt to dynamic situations, and be able to analyze in real-time. The article discusses the uses of AI in robotics, namely automation, precision, predictive maintenance, quality control [35].

Mitchell (2023) Robotics and AI are becoming used to transform induced intelligent manufacturing landscapes. Robotics would provide physical tools that can handle jobs that once took humans a lot of time Robotics with AI can make decisions and streamline procedure. Cumulatively, these technologies are transforming the manufacturing process by making it extremely efficient, less prone to errors that may be made by human beings during manufacturing operations and can enable real-time response to changing demands of production. This paper outlines the use of robotics and AI in smart manufacturing and the advantages of the combination, and gives some examples of the implementation of diversity in a number of industries. Challenges and future trends in this integration are further discussed, providing ideas on the degree to which AI and robotics can transform the manufacturing area [36].

Kovič et al. (2023) paper discusses the electronic technologies and industrial robots applied by manufacturing companies. More importantly, look at the relationship between the use of digital technologies and industrial robots within the industry 4.0 concept. also use a specific Industry 4.0 Readiness index to assess manufacturing firms' Industry 4.0 readiness level and analyze the relationship between the achieved readiness level and the use of industrial robots. The research is based on data from 118 manufacturing firms from a European Manufacturing Survey. Based on statistical analysis, present the results that show a significant correlation between the use of specific digital technologies and two types of industrial robots also points out that manufacturing firms with a higher Industry 4.0 readiness level tend to use industrial robots more frequently [37].

Table I summarizes key studies on AI-powered industrial robots, highlighting their applications, main findings, challenges, and future trends, providing a clear overview of advancements in smart factory environments.

TABLE I. SUMMARY OF LITERATURE REVIEW ON AI-POWERED INDUSTRIAL ROBOTS IN SMART FACTORIES

Author(s)	Study On	Key Findings	Applications	Challenges	Future Trends
Pandy et al. (2025)	Integration of AI in robotics across industries	AI enhances precision, operational efficiency, and autonomous decision-making	Human-robot collaboration, swarm robotics, soft robotics, process automation	Ethical concerns, scalability issues, resource constraints	Technological progress in the areas of learning algorithms, sensors, and human-robot interface
Daely, Permata & Aji (2025)	Pickup & delivery task optimization for carrier robots in smart factories	Edge servers assist robots with task allocation and routing; bio-inspired algorithms optimize performance	Edge-assisted logistics, route planning, task provisioning for carrier robots	Limited to pickup & delivery tasks; communication delays	Distributed AI algorithms for multi-robot task optimization and smart factory logistics

Ikechukwu (2024)	Artificial intelligence robots against humans' effectiveness in logistics and production	AI robots outperform humans in speed, precision, and repetitive tasks; humans better in situational awareness	Automation of repetitive manufacturing/logistics tasks, alternate route selection in logistics	Humans still needed for cognitive and situational tasks; small sample size	Investment in tailored AI-powered robotic systems for industry-specific tasks
Khalid (2024)	AI applications in industrial robotics for manufacturing	Robots powered by artificial intelligence enhance automation, quality control, predictive maintenance, and adaptability.	Quality assurance, process automation, and decision-making in real-time	Lack of real-time deployment studies and multi-robot coordination	Use of AI for complex tasks, real-time decision-making, and adaptive industrial processes
Mitchell (2023)	AI and robotics in smart manufacturing	Integration increases efficiency, reduces human error, and enables process optimization	Smart manufacturing, adaptive production, process optimization	Conceptual focus; limited coverage of advanced AI techniques	Adoption of advanced AI (deep learning, reinforcement learning) for dynamic smart factories
Kovič et al. (2023)	Industrial robots and digital technology as part of Industry 4.0	Manufacturing robot adoption is strongly correlated with digital readiness.	Digital technology adoption, the deployment of industrial robots, and the integration of Industry 4.0	Focused on readiness/adoption rather than operational performance	Linking Industry 4.0 readiness with measurable efficiency, quality, and adaptability improvements

VI. Conclusion and Future Work

AI-powered industrial robots have emerged as a cornerstone of smart factory development, offering the ability to transform conventional production into adaptive, intelligent, and data-driven processes. Their integration enables higher productivity, improved quality control, predictive maintenance, and enhanced collaboration between humans and machines. These innovations lead to safer and more environmentally friendly production settings while simultaneously cutting operational expenses. By leveraging technologies such as IIoT, cloud computing, and computer vision, smart factories are becoming increasingly flexible and resilient, capable of addressing rapidly changing industrial demands. Despite these advantages, challenges such as high implementation costs, system interoperability, safety assurance, and the need for skilled expertise continue to hinder widespread deployment.

Improving interoperability, transparency, and security should be the goal of future robotics R&D. This can be achieved by combining robotics with new technologies like digital twins, blockchain, and 5G IIoT. Advancements in reinforcement learning, human–robot interaction, and ethical AI frameworks will be vital for building socially responsible and user-centric robotic systems. Additionally, interdisciplinary collaboration among engineers, AI specialists, and policymakers will support the creation of standardized guidelines and best practices. Long-term empirical studies and pilot projects will be crucial for validating industrial benefits, ensuring that AI-powered robotics drives sustainable growth and innovation in future manufacturing ecosystems.

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