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Original Article

The Usage of Robots in Various Sectors: Comprehensive Analysis

T. Lakshmi Hasmitha[1], G. Niranjan[2], B. Hemanth[3], D. H S S Abhigna[4]

[1,2,3,4]*Vignan Foundation for Science Technology & Research, Guntur, India.*

[1]*Corresponding Author : tadavarthyhasmitha@gmail.com*

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Abstract *- The integration of robots into numerous sectors has considerably converted industries by means of enhancing performance, productiveness, and protection. This paper examines the packages of robotic generation in production, healthcare, agriculture, logistics, and provider industries. It highlights the blessings of robotics, inclusive of increased operational performance, precision, and worker safety, even as additionally addressing demanding situations, which include high preliminary costs, job displacement, and the want for specialized education via studying present-day developments and future prospects, this studies pursuits to provide a complete knowledge of ways robots are reshaping our international and their ability to power innovation throughout diverse fields.*

Keywords *- Artificial Intelligence, Automation, Collaborative Robots, Logistics, Robotics.*

1. Introduction

The advent of the robotics era has significantly prompted current society, defined as machines able to sport out a series of moves automatically; robots have evolved from easy mechanical gadgets to complicated structures geared up with artificial intelligence (AI) and system-studying competencies. This paper investigates the current landscape of robotic applications, identifying key sectors wherein robots are making substantial impacts. The fast development of the generation has ushered in a brand new technology of innovation, with robotics at the leading edge of this alteration; defined as machines able to sport out a series of actions robotically, robots have advanced significantly from their early mechanical predecessors. To start with, as it evolved for commercial packages, the scope of robotics has improved to encompass various sectors, profoundly impacting how responsibilities are achieved, and services are introduced. Regardless of the numerous benefits, the integration of robotics is not without its demanding situations. Worries concerning process displacement, high implementation fees, and the need for ongoing protection and schooling pose significant barriers to great adoption. As industries continue to adapt, understanding the implications of robotics in the workforce and society becomes increasingly critical.

2. Literature Review

This paper, given by Riza Sulaiman et al., investigates the use of 3G mobile technology for controlling mobile robots, focusing on data transfer techniques and prototype development to enhance mobile device usability in robotics.[1] The paper of Tsolmon Myagmarjav explores the use of image processing techniques, enhanced by OpenCV, in conjunction with an ABB IRB 120 industrial robot arm for quality assurance by distinguishing normal and abnormal products in production.[2] The paper of Ivan Petrovic presents a mobile robot pose-tracking approach using laser scan readings, histograms, and correlation comparison to enhance localization accuracy and reliability for autonomous service robots.[3] The paper of Surya A presents a wireless, hand gesture-controlled robotic chassis using OpenCV and deep learning for intuitive operation, enabling real-time control and live video streaming via a Zigbee module[4].

The paper of Habib Ahmed explores the integration of robotics in education, focusing on its role in STEM learning and broader educational applications while proposing a model for a sustainable Education-Robotics symbiosis with policy implications.[5] The paper by Whee Jae Yim analyses mobile robot navigation using the Vector Field Histogram (VFH) algorithm, identifying optimal sector configurations for successful navigation under various driving and environmental conditions[6]. The paper by Alexandra Dobrokvashina reviews industrial robots used in human-robot collaboration and explores safety strategies for ensuring secure interaction during collaborative tasks in manufacturing sectors[7]. The paper by R. Rizal Isnanto develops an IoT-based robot using the ESP-NOW protocol to monitor and maintain soil conditions autonomously, achieving real-time communication and optimal agricultural parameters[8]. The paper of Amily Fikry reviews the growing adoption of robotic technology in healthcare during and after the COVID-19 pandemic, highlighting its benefits, challenges, and impact on reducing cross-infection risks.[9] The paper of Tigor Hamonangan Nasution presents the design of an autonomous robot that detects human presence and measures body temperature using ultrasonic and PIR sensors, with audio and LCD output, for COVID-19 prevention in the healthcare sector.

3. Robotics in Manufacturing

3.1. Overview of Robotics in Manufacturing

The healthcare sector has seen a transformative integration of the robot era, improving patient care, improving surgical precision, and optimizing hospital operations. From robotic surgical structures to rehabilitation devices, robots are playing an increasingly critical role in various healthcare applications.

3.2. Current Applications

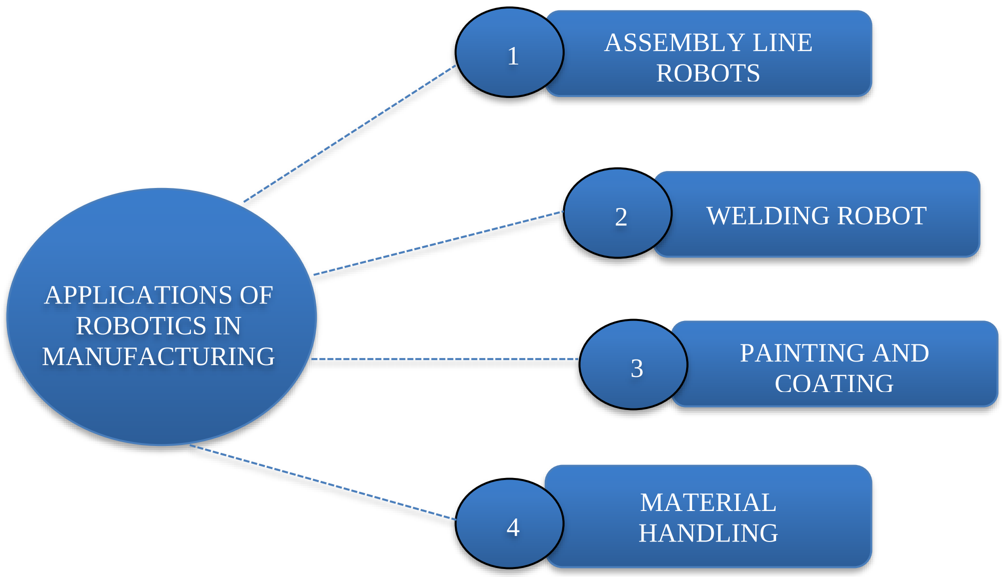

Fig. 1 Application of robotics in manufacturing

3.2.1. Assembly Line Robots

These robots carry out repetitive duties with excessive precision, operating alongside human operators or independently to gather products fast and as they should be.

3.2.2. Welding Robots

Automatic welding machines are used extensively in automobile and heavy machinery industries, presenting consistent fine and decreasing exertion costs.

3.2.3. Painting and Coating

Robots equipped with spray guns make certain uniform applications of paints and coatings, improving product finish and reducing waste.

3.2.4. Material Handling

Automated Guided Vehicles (AGVs) and robot arms are employed to move substances within centers, streamlining logistics and reducing manual exertions.

3.3. Advantages

The integration of robotics in manufacturing offers numerous benefits, including:

3.3.1. Increased Production Efficiency

Robots can perform continuously with out fatigue, significantly increasing output and reducing lead times.

3.3.2. Enhanced Precision and Quality Control

Automation minimizes human error, resulting in better quality products and less defects.

3.3.3. Worker Safety

Robots are able to perform risky obligations, consisting of dealing with hazardous materials or operating in excessive environments, thereby reducing workplace accidents.

3.3.4. Flexibility and Adaptability

Modern robots can be programmed and reconfigured for various tasks, allowing manufacturers to reply quickly to changes in demand or product design.

3.4. Challenges

Despite the many advantages, the adoption of robotics in manufacturing is accompanied by several challenges:

3.4.1. High Initial Investment

The cost of acquiring and implementing robotic systems may be substantial, particularly for Small and Medium-sized Enterprises (SMEs).

3.4.2. Job Displacement

The fear of automation replacing human jobs is an extensive concern, leading to resistance from people and labor unions.

3.4.3. Technical Complexity

The integration of robotics into current manufacturing procedures requires advanced technical capabilities, necessitating education and ongoing maintenance.

3.4.4. Dependence on Technology

Over-reliance on robotic systems can lead to vulnerabilities, particularly if technical failures occur or if systems are not adequately maintained.

3.5. Future Trends

The future of robotics in manufacturing is promising, with ongoing advancements in artificial intelligence, machine learning, and collaborative robotics (cobots). These developments will likely enhance the capabilities of robots, enabling them to work more effectively alongside human operators and adapt to dynamic manufacturing environments. The trend toward Industry 4.0—characterized by smart factories and interconnected systems—will further drive the adoption of robotics, leading to more efficient and responsive manufacturing processes.

4. Robotics in Healthcare

4.1. Overview of Robotics in Healthcare

The healthcare sector has seen a transformative integration of robotic technology, improving patient care, enhancing surgical precision, and optimizing hospital operations. From robot surgical systems to rehabilitation devices, robots are gambling an an increasing number of important roles in diverse healthcare packages.

4.2. Applications

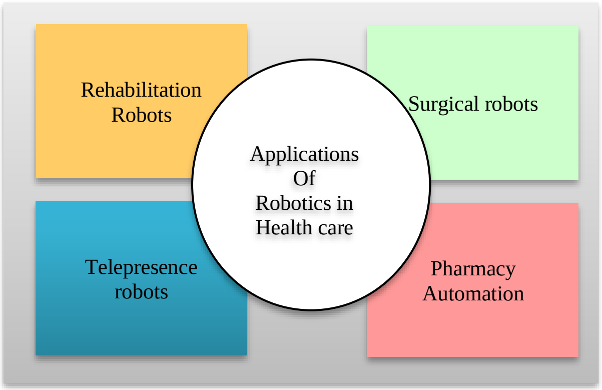

Fig. 2Applications of robotics in health care

Robotics in healthcare encompasses a wide range of applications, including:

4.2.1. Surgical Robots

Systems such as the da Vinci Surgical device allow surgeons to perform minimally invasive procedures with enhanced precision. Those robots provide better visualization and control, resulting in less trauma to patients and quicker recovery times.

4.2.2. Rehabilitation Robots

Devices designed to assist patients in regaining mobility post-injury or surgery are becoming more prevalent. These robots can provide tailored therapy, adjusting to the individual needs of each patient, thereby enhancing rehabilitation outcomes.

4.2.3. Telepresence Robots

These robots enable remote consultations, allowing healthcare professionals to interact with patients from a distance. This is particularly valuable in rural areas where access to specialists may be limited.

4.2.4. Pharmacy Automation

Robots are increasingly used in hospitals to automate medication dispensing, reducing the likelihood of errors and improving inventory management.

4.3. Advantages

The application of robotics in healthcare offers numerous benefits:

4.3.1. Improved Patient Outcomes

Robotic-assisted surgeries generally lead to less pain, reduced scarring, and shorter hospital stays. Rehabilitation robots provide consistent and targeted therapy, improving recovery rates.

4.3.2. Increased Precision and Control

Surgical robots enhance the surgeon's ability to perform delicate procedures with greater accuracy, leading to better overall results.

4.3.3. Enhanced Efficiency

Automation in pharmacies and administrative tasks allows healthcare staff to focus on direct patient care, optimizing workflow and resource allocation.

4.3.4. Remote Access to Care

Telepresence robots bridge gaps in healthcare access, ensuring that patients in remote areas can receive expert consultations without the need for extensive travel.

4.4. Challenges

Despite the numerous advantages, the integration of robotics in healthcare also presents several challenges:

4.4.1. High Costs

The initial investment required for robotic systems can be substantial, making it difficult for some healthcare facilities to adopt this technology.

4.4.2. Training Requirements

Healthcare professionals must undergo specialized training to operate robotic systems effectively, which can be time-consuming and resource-intensive.

4.4.3. Technological Dependence

Reliance on robotic systems may create vulnerabilities, especially if technical failures occur during critical procedures.

4.4.4. Regulatory and Ethical Considerations

The use of robotics in healthcare raises ethical questions about patient safety, data privacy, and the implications of automated decision-making.

4.5. Future Trends

The future of robotics in healthcare is promising, with ongoing advancements in artificial intelligence and machine learning expected to enhance robotic capabilities. As technology continues to evolve, we can anticipate:

4.5.1. Greater Integration of AI

Intelligent systems will likely improve diagnostics and treatment planning, leading to more personalized care.

4.5.2. Enhanced Rehabilitation Technologies

Innovations in wearable robotics and exoskeletons will provide further support for rehabilitation, helping patients regain mobility more effectively.

4.5.3. Expansion of Telehealth

As telepresence robots become more sophisticated, their use in routine healthcare will likely increase, enabling broader access to specialized care.

4.5.4. Collaborative Robots (Cobots)

These robots will work alongside healthcare professionals, assisting in routine tasks and allowing for a more efficient distribution of labor in clinical settings.

5. Robotics in Agriculture

5.1. Overview of Robotics in Agriculture

Robotics is revolutionizing agriculture by enhancing efficiency, precision, and productivity in farming operations. As the global population continues to grow, the demand for food increases, necessitating innovative solutions to meet agricultural challenges.

Robotics technology addresses issues such as labor shortages, the need for sustainable practices, and the optimization of resource use.

5.2. Applications

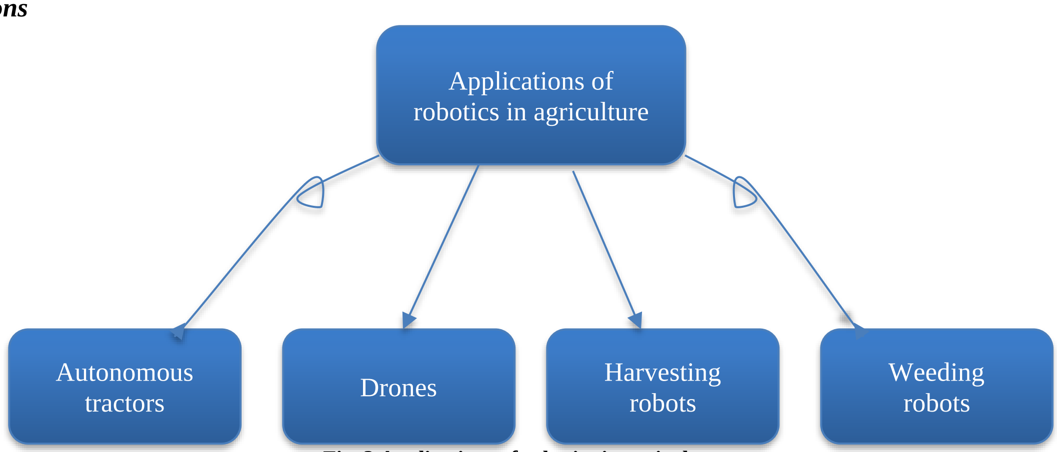

Fig. 3 Applications of robotics in agriculture

Robotic systems are utilized across various agricultural processes, including:

5.2.1. Autonomous Tractors

These self-driving vehicles can perform tasks such as ploughing, planting, and harvesting with minimal human intervention. Equipped with GPS and sensors, they ensure accurate and efficient field operations.

5.2.2. Drones

Unmanned Aerial Vehicles (UAVs) are employed for crop monitoring, mapping, and surveillance.

Drones can assess crop health, identify pest infestations, and evaluate soil conditions, providing valuable data for informed decision-making.

5.2.3. Harvesting Robots

Specialized robots equipped with advanced sensors and machine vision can identify ripe fruits and vegetables and harvest them with precision. This automation helps address labor shortages and reduces waste.

5.2.4. Weeding Robots

These robots autonomously identify and remove weeds using various techniques, including mechanical removal and targeted herbicide application. This helps to minimize chemical usage and promotes sustainable farming practices.

5.3. Advantages

The integration of robotics in agriculture offers several key benefits:

5.3.1. Increased Efficiency

Robots can operate continuously and perform tasks faster than human laborers, significantly boosting productivity on farms.

5.3.2. Precision Agriculture

Robotics allows for the precise application of inputs (e.g., water, fertilizers, pesticides), reducing waste and optimizing resource use. This leads to higher yields and lower environmental impact.

5.3.3. Labor Shortages

Automation addresses the declining labor force in agriculture, particularly in regions facing workforce shortages. Robots can take on labor-intensive tasks, freeing human workers for more skilled positions.

5.3.4. Data-Driven Decision-Making

The use of drones and sensors enables farmers to collect and analyze data on crop health and environmental conditions, leading to better-informed management practices.

5.4. Challenges

Despite the numerous advantages, the adoption of robotics in agriculture faces several challenges:

5.4.1. High Initial Costs

The investment required for robotic systems can be substantial, particularly for small-scale farmers. This may hinder widespread adoption.

5.4.2. Technical Complexity

Implementing and maintaining advanced robotic systems require specialized knowledge and training, which may not be readily available in all farming communities.

5.4.3. Reliability and Adaptability

Agricultural environments are unpredictable, and robots must be able to adapt to various conditions, such as changes in weather or terrain. Ensuring reliability in such settings can be challenging.

5.4.4. Public Acceptance

There may be resistance to the use of automation in agriculture due to concerns about job displacement and the loss of traditional farming practices.

5.5. Future Trends

The future of robotics in agriculture is promising, driven by technological advancements and the growing need for sustainable practices. Anticipated trends include:

5.5.1. Enhanced AI and Machine Learning

The integration of AI will improve the decision-making capabilities of robotic systems, enabling better predictions regarding crop health and resource needs.

5.5.2. Robust Data Analytics

Advances in data analytics will allow for more sophisticated monitoring and management of agricultural practices, leading to increased efficiency and sustainability.

5.5.3. Collaboration with Human Workers

The emergence of collaborative robots (cobots) will facilitate a new model where robots assist human farmers, enhancing productivity while preserving jobs.

5.5.4. Sustainable Farming Practices

Robotics will play a crucial role in promoting sustainable agriculture by minimizing chemical usage, reducing waste, and optimizing resource use.

6. Robotics in Logistics

6.1. Overview of Robotics in Logistics

The logistics industry is undergoing a significant transformation driven by advancements in robotic technology. As e-commerce continues to expand and consumer expectations for fast, efficient delivery increase, robotics plays a critical role in optimizing supply chain operations. From warehousing to last-mile delivery, robots enhance efficiency, accuracy, and safety in logistics processes.

6.2. Applications

Robotic systems are utilized across various logistics operations, including:

6.2.1. Warehouse Automation

Automated Storage and Retrieval Systems (AS/RS) and robotic picking systems streamline inventory management. Robots can swiftly locate and transport items, reducing manual labor and increasing throughput.

6.2.2. Automated Guided Vehicles (AGVs)

These self-driving vehicles transport goods within warehouses or distribution centers. Equipped with sensors and navigation systems, AGVs optimize material handling and reduce the risk of human error.

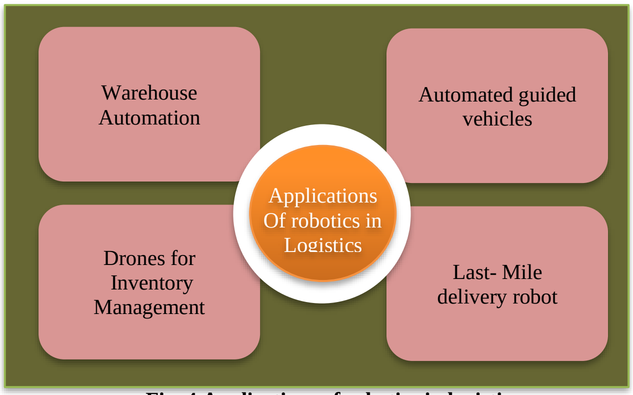

Fig. 4 Applications of robotics in logistics

6.2.3. Drones for Inventory Management

Drones equipped with cameras and RFID technology can conduct inventory checks in large warehouses, providing real-time data on stock levels and locations.

6.2.4. Last-Mile Delivery Robots

Autonomous delivery vehicles and robots are emerging as solutions for last-mile logistics, transporting goods directly to consumers' doorsteps. These robots help reduce delivery times and costs, particularly in urban environments.

6.3. Advantages

The integration of robotics in logistics offers numerous benefits:

6.3.1. Increased Efficiency

Robots can operate continuously, significantly improving processing speeds and reducing turnaround times for orders.

6.3.2. Cost Savings

Automation reduces labor costs and minimizes the risk of human error, leading to cost efficiencies throughout the supply chain.

6.3.3. Improved Accuracy

Robotic systems enhance inventory management and order fulfillment accuracy, reducing errors and improving customer satisfaction.

6.3.4. Safety Enhancement

Robots can perform hazardous tasks, such as handling heavy loads or working in challenging environments, thereby improving workplace safety for human workers.

6.4. Challenges

Despite the many advantages, the adoption of robotics in logistics faces several challenges:

6.4.1. High Initial Investment

The upfront costs of implementing robotic systems can be significant, posing a barrier for Small and Medium-sized Enterprises (SMEs).

6.4.2. Integration with Existing Systems

Adapting robotic technology to existing logistics operations may require substantial changes to infrastructure and processes, which can be complex and disruptive.

6.4.3. Technical Complexity

The management and maintenance of robotic systems necessitate specialized knowledge and training, which may not be readily available in all logistics firms.

6.4.4. Regulatory Hurdles

The deployment of autonomous delivery vehicles and drones faces regulatory challenges, including safety standards and operational guidelines.

6.5. Future Trends

The future of robotics in logistics is promising, with continued innovation expected to drive further integration of technology. Anticipated trends include:

6.5.1. Artificial Intelligence and Machine Learning

The use of AI will enhance the decision-making capabilities of robotic systems, allowing for improved route optimization, demand forecasting, and operational efficiency.

6.5.2. Collaborative Robotics

The development of cobots that work alongside human workers will create more flexible and efficient workflows, enhancing productivity and safety.

6.5.3. Expanded Use of Drones

As regulations evolve, the use of drones for inventory management and last-mile delivery will likely increase, further streamlining logistics operations.

6.5.4. Sustainability Initiatives

Robotics will play a role in promoting sustainable logistics practices by optimizing delivery routes, reducing energy consumption, and minimizing waste.

7. Robotics in Service industries

7.1. Overview of Robotics in Service Industries

Robotics is increasingly being integrated into service industries, transforming how businesses operate and interact with customers. From hospitality and retail to healthcare and customer service, robots are enhancing efficiency, improving customer experiences, and reducing operational costs. As consumer expectations rise for faster and more personalized services, robotics presents innovative solutions to meet these demands.

7.2. Applications

Robotic systems are utilized in various service industry applications, including:

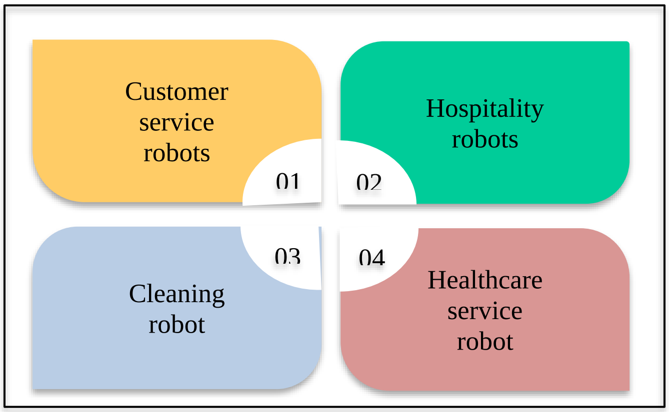

Fig. 5 Applications of robotics in service industries

7.2.1. Customer Service Robots

Robots are being deployed in retail environments to assist customers with inquiries, provide product information, and enhance the shopping experience. These robots can guide customers through stores and offer personalized recommendations based on preferences.

7.2.2. Hospitality Robots

In hotels and restaurants, robots are used for tasks such as room service delivery, cleaning, and even cooking. For instance, robotic waitstaff can deliver food and drinks to tables, enhancing efficiency and freeing up human staff for more complex interactions.

7.2.3. Healthcare Service Robots

Robots are increasingly used in healthcare settings for tasks such as medication delivery, patient monitoring, and support for elderly or disabled individuals. These applications improve efficiency in care delivery and enhance patient safety.

7.2.4. Cleaning Robots

Autonomous cleaning machines are utilized in commercial spaces, such as airports, shopping malls, and offices. These robots perform routine cleaning tasks, ensuring cleanliness and hygiene while minimizing labor costs.

7.3. Advantages

The integration of robotics in service industries offers several key benefits:

7.3.1. Enhanced Customer Experience

Robots provide efficient and consistent service, leading to improved customer satisfaction. Personalized interactions through AI-enabled robots can create tailored experiences for users.

7.3.2. Cost Efficiency

Automation of routine tasks allows businesses to reduce labor costs and allocate human resources to more complex and value-added activities.

7.3.3. Increased Operational Efficiency

Robots can work continuously without breaks, increasing productivity and ensuring timely service delivery.

7.3.4. Improved Safety and Hygiene

In sectors like hospitality and healthcare, robots can help maintain high hygiene standards, reducing the risk of contamination and improving overall safety.

7.4. Challenges

Despite the numerous advantages, the adoption of robotics in service industries faces several challenges:

7.4.1. Public Acceptance

There may be resistance from customers regarding interactions with robots, particularly in roles traditionally held by humans. Concerns about job displacement and the quality of service provided by robots can affect acceptance.

7.4.2. Technical Limitations

Current robotic technology may struggle with complex tasks that require human intuition, empathy, and understanding, limiting the scope of automation.

7.4.3. Integration Costs

The initial investment in robotic systems and the necessary infrastructure can be substantial, particularly for small businesses.

7.4.4. Maintenance and Support

Ongoing maintenance and updates are required to ensure that robotic systems function effectively, necessitating technical expertise and resources.

7.5. Future Trends

The future of robotics in service industries is poised for growth, with several trends expected to shape its evolution:

7.5.1. AI and Machine Learning Integration

As AI technology advances, service robots will become more adept at understanding customer preferences and providing personalized interactions.

7.5.2. Increased Collaboration Between Humans and Robots

The emergence of collaborative robots (cobots) will create environments where robots and human workers work together seamlessly, enhancing productivity and service quality.

7.5.3. Expansion of Autonomous Delivery Services

The use of robots for delivery services will likely increase, particularly in urban areas, offering faster and more efficient options for consumers.

7.5.4. Sustainability Initiatives

Robotics can help promote sustainability in service industries by optimizing resource use, reducing waste, and improving energy efficiency in operations.

8. Conclusion

The integration of robots into various sectors has undeniably transformed industries, driving efficiency, productivity, and safety. From manufacturing and agriculture to healthcare and logistics, robots are increasingly taking on tasks that are repetitive, dangerous or require high levels of precision. This comprehensive analysis illustrates that the deployment of robotic technology not only streamlines operations but also helps address workforce shortages and enhances service quality. In healthcare, for example, robots have played a crucial role during public health crises, such as the COVID-19 pandemic, by reducing the risk of infection and improving patient monitoring. Additionally, the capabilities of robots in performing complex tasks continue to expand, paving the way for new applications and opportunities across diverse fields.

However, while the benefits of robotic technology are substantial, several challenges and ethical considerations accompany their adoption. Issues such as high implementation costs, the need for specialized training, and concerns regarding job displacement must be carefully addressed to facilitate a smooth transition to an automated future. Moreover, the rapid advancement of robotics and artificial intelligence raises questions about governance, accountability, and societal impact. It is crucial for stakeholders—manufacturers, policymakers, and educators—to collaborate in developing frameworks that ensure the responsible deployment of robotics. This collaboration will not only maximize the benefits of robotic technology but also safeguard against potential pitfalls, ensuring that the shift toward automation contributes.

Acknowledgments

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