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The Role of Artificial Intelligence in Shaping Robotics Innovation

Abdulrahman Mohammed Zagibah[a]*
[a] Computing Science. University of Alberta. 5-140 University Commons. Edmonton, Alberta, Canada

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A B S T R A C T

Applying Artificial Intelligence in Robotics is a revolutionary move in industries, education, and the health sector. In this paper, we critically survey recent work in the literature to analyse the ways AI is influencing robotics innovation, emphasizing both its potential and its limitations. The results show that AI-enabled robotics improves efficiency and flexibility in industrial applications, enabling predictive maintenance, smart manufacturing, and operational resilience. In education, interactive and voice-activated robots promote student engagement, problem-based learning, and progressive pedagogy, but uneven access may reinforce digital divides. In medicine, AI-based surgery and diagnostics robots enable greater precision, fewer mistakes, and better patient outcomes, but raise unanswered ethical questions regarding accountability, autonomy, and patient–doctor trust. In addition to applications in industry, mandates from society, ethics, and regulation are also recognized as barriers to unfettered use. Problems of data privacy, transparency, and fairness remain, while high adaptation costs and immature regulatory frameworks limit the spread. The findings suggest that AI in robotics is both a technical disruptor and a social transformer, offering a wealth of opportunities while requiring robust ethical governance. The paper concludes by suggesting that drawing on the expertise of multiple disciplines – stemming from the work of engineers, ethicists, and policymakers- and engaging key stakeholders, AAI-powered robotics will continue to evolve for the better. More work is needed on governance models, inclusiveness, and long-range societal consideration to strike a balance between innovation and responsibility.

الملخص

يُعد تطبيق الذكاء الاصطناعي في الروبوتات نقلة نوعية في الصناعات والتعليم والقطاع الصحي. في هذه الورقة البحثية، نستعرض بشكل نقدي أحدث الدراسات المنشورة لتحليل كيفية تأثير الذكاء الاصطناعي على ابتكارات الروبوتات، مع التركيز على إمكاناته وحدوده. تُظهر النتائج أن الروبوتات المدعومة بالذكاء الاصطناعي تُحسّن الكفاءة والمرونة في التطبيقات الصناعية، مما يُتيح الصيانة التنبؤية والتصنيع الذكي والمرونة التشغيلية. في التعليم، تُعزز الروبوتات التفاعلية والصوتية مشاركة الطلاب والتعلم القائم على حل المشكلات ومنهجية التدريس التقدمية، إلا أن عدم تكافؤ فرص الوصول قد يُعزز الفجوات الرقمية. في الطب، تُتيح روبوتات الجراحة والتشخيص القائمة

* Corresponding author.
E-mail address: abd.Zagibah@ualberta.ca
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على الذكاء الاصطناعي دقة أكبر وأخطاء أقل ونتائج أفضل للمرضى، لكنها تُثير أسئلة أخلاقية لم تُجب عليها بعد تتعلق بالمساءلة والاستقلالية وثقة المريض بالطبيب. بالإضافة إلى تطبيقاتها في الصناعة، تُعتبر متطلبات المجتمع والأخلاقيات واللوائح عوائق أمام الاستخدام غير المقيد. لا تزال مشاكل خصوصية البيانات والشفافية والعدالة قائمة، بينما تُحدّ تكاليف التكيف المرتفعة والأطر التنظيمية غير الناضجة من انتشارها. تشير النتائج إلى أن الذكاء الاصطناعي في مجال الروبوتات يُحدث ثورة تقنية ويُحدث تحولاً اجتماعياً في آنٍ واحد، إذ يُتيح فرصاً واعدة مع ضرورة وجود حوكمة أخلاقية متينة. وتُختتم الورقة البحثية بالإشارة إلى أن الروبوتات المدعّمة بالذكاء الاصطناعي ستواصل تطورها نحو الأفضل، بالاستفادة من خبرات تخصصات متعددة – نابعة من عمل المهندسين وعلماء الأخلاقيات وصانعي السياسات – وإشراك أصحاب المصلحة الرئيسيين. ويلزم مزيد من العمل على نماذج الحوكمة، والشمولية، والاعتبارات المجتمعية بعيدة المدى لتحقيق التوازن بين الابتكار والمسؤولية.

JEL Classification: *O33; L86; I21; & J24.*

1. Introduction

The integration of Artificial Intelligence (AI) into robotics represents a critical turning point in technological evolution, particularly in the context of Industry 4.0. The synergy between AI and robotics has advanced automation, enhanced decision-making, and fostered adaptability across multiple domains such as manufacturing, healthcare, and education (Sodiya et al., 2024; Mia & Shuford, 2024). AI-driven robotics not only improves efficiency and resilience in industrial operations but also expands the scope of robotic applications into domains traditionally reliant on human expertise, such as surgery, caregiving, and personalized education (Osman et al., 2025; Castro-Inostroza et al., 2024). These developments demonstrate the strong motive behind integrating AI with robotics: to achieve greater precision, flexibility, and societal impact through intelligent, adaptive systems. Despite these transformative potentials, a number of persistent problems temper the enthusiasm surrounding AI-enabled robotics. Key among these are ethical dilemmas linked to autonomy, accountability, and human replacement. In sensitive contexts such as elder care, healthcare, or social interaction, delegating decision-making to AI-driven robots raises questions about moral responsibility and the erosion of human contact (Iftikhar et al., 2024; Vozna & Costantini, 2025; Masala & Giorgi, 2025). Moreover, the growing reliance on intelligent robotic systems amplifies concerns about data security and privacy, particularly as personal health and behavioral data are increasingly processed by machines (Ibuki et al., 2023; Tsur & Elkana, 2024). These risks underscore the need for governance frameworks that ensure transparency, fairness, and user trust, without impeding the pace of innovation.

Another challenge lies in the uneven adoption of AI-driven robotics across industries. While some organizations successfully deploy AI-enabled robots for predictive maintenance or surgical assistance, others struggle due to prohibitive costs, a shortage of expertise, and underdeveloped regulatory environments ("Innovative Applications of AI in Robotics: A Comprehensive Study", 2024; Ness et al., 2024). Such barriers limit scalability, especially in small and medium enterprises and in regions with weak technological infrastructures. The gap between technological potential and actual implementation thus reflects not merely a technical problem, but a socio-economic and policy-oriented challenge requiring collaborative solutions. Within this context, clear research gaps emerge. While technical advances in machine learning, computer vision, and natural language processing have significantly enhanced robotic capabilities (Singh & Singh, 2023; Chen et al., 2024; Zhao et al., 2023), less progress has been made in addressing the ethical, regulatory, and socio-economic implications of widespread adoption. Questions remain about how to balance innovation with accountability, how to safeguard privacy in increasingly autonomous systems, and how to create equitable access to AI-enabled robotics in both developed and emerging markets (Charllo, 2024; Osman et al., 2025). These gaps highlight the necessity of interdisciplinary approaches that integrate engineering innovations with ethical reflection, policy design, and societal engagement. Thus, the role of AI in shaping robotics innovation is both promising and complex. The motive behind AI-robotics integration lies in its ability to drive unprecedented improvements in efficiency, adaptability, and service delivery. The problems, however, stem from ethical dilemmas, data security risks, and uneven adoption across industries. The research gap calls for a deeper critical discourse that situates robotics innovation not only within technical achievement but also within societal, ethical, and regulatory frameworks. Addressing this gap is crucial for ensuring that the transformative power of AI-enabled robotics is harnessed responsibly and inclusively for the benefit of all stakeholders.

2. Literature Review

AI has emerged as a pivotal force in shaping robotics innovation across multiple sectors, where its integration has not only enhanced efficiency and productivity but also introduced entirely new service paradigms. The fusion of AI with robotics is increasingly viewed as a transformative driver of technological change, illustrating how this synergy is reshaping the future of industry and society. Scholars argue that the convergence of AI and robotics underpins the broader trajectory of Industry 4.0, where intelligent automation becomes central to competitiveness and resilience (Ness et al., 2023; Mia & Shuford, 2024). Yet, while the technological potential is clear, critical reflection is needed on how such advancements reconfigure socio-economic structures and challenge traditional modes of operation. A fundamental dimension of AI's influence is evident in industrial applications, particularly through the transformation of manufacturing processes. The collaboration between AI and robotics enables predictive maintenance, enhanced quality control, and optimized workflow management, all of which contribute to greater operational efficiency (Ness et al., 2023; Mia & Shuford, 2024). Importantly, adaptive learning mechanisms embedded within AI-driven robots allow these systems to continuously refine their performance, aligning with fluctuating industrial demands and market uncertainties (Zhu & Wang, 2024). However, critics highlight that such automation also risks displacing labor, thereby demanding careful evaluation of its economic and social consequences.

The educational sector represents another domain where AI-enabled robotics has begun to exert influence, creating new opportunities for pedagogy and skill development. For example, voice-controlled robotic systems offer novel means of engaging young learners, lowering barriers to participation, and fostering interactive learning experiences (Castro-Inostroza et al., 2024). Beyond enhancing classroom engagement, robotics education encourages the cultivation of critical thinking and problem-solving skills, equipping students with competencies essential for a technology-driven future (Zuo et al., 2023; Khan et al., 2023). Nevertheless, questions remain regarding equity of access, as the deployment of robotics in education often reflects disparities in resources across different educational systems. In healthcare, AI-driven robotics is particularly promising but equally complex. Surgical robots enhanced with AI capabilities demonstrate potential to increase precision, reduce complications, and improve patient outcomes, thereby advancing surgical efficiency and reliability (Hirschmann et al., 2024). At the same time, AI-driven innovations extend beyond surgery to broader applications such as diagnostics and patient care, reinforcing a paradigm shift in how medical services are delivered (Vatkar et al., 2023). Yet, these advancements also raise ethical questions about accountability in life-critical decisions, emphasizing the need for robust oversight and transparency. Collectively, these advancements illustrate that the integration of AI and robotics is not merely a technical innovation but also a societal transformation. The evolving landscape points toward a redefinition of labor markets, healthcare practices, and educational models, while simultaneously underscoring the importance of ethical governance (Çağal & Keskin, 2023). Thus, while AI is rightly positioned as a cornerstone of modern robotics, its role extends beyond efficiency gains to the reshaping of fundamental societal structures. Recognizing both the opportunities and risks associated with these technologies is essential to ensuring their responsible and inclusive deployment.

2.1 Historical and Conceptual Foundations

The evolution of artificial intelligence (AI) applications in robotics has transformed the landscape of various industries by enhancing autonomy and adaptability. The integration of AI with robotics represents a significant technological advancement, leading to the proliferation of intelligent automated systems capable of performing complex tasks autonomously. This convergence has been characterized as a key driver in developing state-of-the-art technologies, enhancing productivity, and facilitating innovative industry practices, as discussed by Ness et al. (2023) and further evidenced by Mia and Shuford (Mia & Shuford, 2024). AI enhances robotics through its computational capabilities, allowing robots to learn from their environments and adapt to dynamic situations. For instance, AI-driven robotics empowers machines to perform tasks ranging from manufacturing to healthcare, making them more efficient and capable of independent functioning (Nishad et al., 2024; Miao et al., 2023). The integration of AI enables robots to analyze vast amounts of data, recognize patterns, and make informed decisions in real-time, thus significantly advancing automation and operational effectiveness (Mia & Shuford, 2024; Wang, 2024). Notably, AI-driven robotics has gained traction in the medical field, particularly with robotic surgery applications. Rivero-Moreno et al. (2024) illustrate how AI integration enables greater autonomy in surgical procedures, despite challenges such as the need for haptic feedback. The implications of AI in healthcare extend beyond surgery; the development of intelligent medical robots is undergoing rapid advancements aimed at improving patient care (Miao et al., 2023; Knudsen et al., 2024). These applications underscore the essential role AI plays in enhancing the functionality and adaptability of robots within critical sectors. Furthermore, the contextual application of AI in robotics varies across industries. In manufacturing, intelligent robotics, leveraged by AI, allows for personalized production lines and predictive maintenance, which substantially improves operational processes (Mia & Shuford, 2024; Wang, 2024). Additionally, in the service sector, particularly in hospitality and tourism, the application of service robots enhanced by AI represents an evolution in customer interaction and service delivery, demonstrating increased efficiency and a shift in service paradigms (Sun et al., 2024; Molfino et al., 2023). Thus, the historical and conceptual foundations of AI applications in robotics reveal a transformation that underscores increased autonomy, adaptability, and efficiency across various applications. The continual advancement of AI technologies amplifies the scope and capability of robots, thereby redefining operational standards across industries. As research progresses, the synergy between AI and robotics will likely foster further innovations, expanding the potential for these technologies to address both existing and unforeseen challenges in diverse fields.

2.2 Core Technological Contributions

The intersection of machine learning, computer vision, and natural language processing (NLP) has catalyzed significant advancements in robotics, leading to innovations that enhance the capabilities of robots in various applications. Machine learning techniques empower robots to improve their perception and decision-making capacities by enabling them to learn from experience, spot patterns, and adapt to complex environments. For instance, recent studies illustrate that robots equipped with machine learning algorithms can autonomously optimize their behaviors in real-time, effectively managing tasks across diverse domains such as manufacturing and logistics (Singh & Singh, 2023; Aggarwal & Professor, 2023).

Computer vision, as an essential component of robotics, synergizes with machine learning to enable robots to interpret visual data, facilitating tasks ranging from object recognition to autonomous navigation. This dual approach enhances robotic perception, allowing for more efficient interactions in dynamic environments, where robots can evaluate and respond to their surroundings more effectively (Chen et al., 2024). Moreover, advancements in visual recognition algorithms support robots in processing complex visual scenes, significantly improving their operational efficiency and accuracy in real-world settings.

Concurrently, NLP plays a crucial role in human-robot interaction by allowing robots to understand and respond to natural language commands. Recent developments indicate that robots can now process linguistically defined instructions with improved precision, thus enabling non-expert users to engage with robotic systems more intuitively (Hernández et al., 2024; Koubâa et al., 2024). Furthermore, the integration of large language models (LLMs) has demonstrated potential in converting natural language inputs into actionable robotic behaviors, effectively bridging the communication gap between humans and machines (Stella et al., 2023; Zhao et al., 2023). In particular, frameworks such as ExTraCT allow robots to adapt their actions in response to complex language directives, thus enhancing user experience in human-robot collaboration (Yow et al., 2024).

The implications of these technological advancements extend into various fields. For instance, the utilization of machine learning and NLP in healthcare robotics enhances patient interaction and care delivery systems by enabling robots to interpret medical commands and user queries effectively (Glauser et al., 2023; Lareyre et al., 2023). Consequently, this convergence of technologies enhances the versatility and efficacy of robots in their operating environments, providing significant advancements in sectors such as service delivery and autonomous navigation.

In summary, the integration of machine learning, computer vision, and NLP fundamentally reshapes the landscape of robotics, fostering a future where robots can perform complex tasks autonomously while ensuring seamless communication with human users. This blend of AI-driven approaches not only amplifies the functional capabilities of robots but also democratizes access to their use, making them increasingly viable across diverse applications. As research progresses, continued exploration of these synergies is expected to unveil further enhancements in robot design and functionality, positioning them as indispensable partners in both industrial and personal contexts.

2.3 Domain-Specific Applications

The integration of AI and robotics in various domains is revolutionizing industries, significantly impacting healthcare, industrial operations, and enhancing human-robot interactions. This synthesis examines domain-specific applications of AI in industrial robotics, healthcare, service robots, and autonomous vehicles, underlining their benefits and challenges reinforced by multiple scholarly sources.

1. AI in Industrial Robotics: Improving Efficiency and Precision

Industrial robotics have increasingly benefitted from AI algorithms, particularly in automation and operational efficiency. AI enhances the decision-making capabilities and learning processes of robots, enabling them to adapt and optimize workflows in real-time, thereby improving both precision and efficiency in manufacturing environments (Li, 2024). The integration of AI empowers robots to undertake complex tasks with minimal human intervention, optimizing production lines and reducing errors (Cruz et al., 2024). For instance, automated guided vehicles (AGVs) utilize AI to navigate through warehouses and factories, contributing to significant time savings and operational efficiency (Li, 2024).

2. Healthcare Robotics and AI: Transforming Patient Care and Assistance

AI and robotics are fundamentally transforming healthcare delivery, enhancing patient care and operational efficiency. Notable applications include surgical robots, like the da Vinci Surgical System, which offer minimally invasive procedures, improved accuracy, and enhanced control (Pushpan & P, 2024). Such technologies have been shown to reduce recovery times and complications associated with traditional surgical methods (Giansanti, 2025). Furthermore, AI applications in diagnostics, such as digital imaging for diabetic retinopathy screening, demonstrate AI's potential to expedite data processing and improve diagnostic accuracy (Lan et al., 2022). Training healthcare professionals to use these technologies is crucial, as studies show an increase in the adoption of AI tools when there's institutional support and adequate training (Cheng et al., 2022).

3. AI-Powered Service and Social Robots: Enhancing Human–Robot Interaction

Social robots, which are increasingly prevalent in caregiving and educational settings, utilize AI to foster meaningful interactions with humans. These robots are designed to assist in therapy, particularly for individuals with autism, where tailored interactions can lead to improved social engagement (Vozna & Costantini, 2025). The growing reliance on Socially Assistive Robots (SARs) for elder care is also notable, providing companionship and support to reduce feelings of loneliness among the elderly (Masala & Giorgi, 2025). However, the introduction of these technologies raises ethical concerns around autonomy, privacy, and the safety of users, which necessitates thorough scrutiny and regulation (Luo et al., 2022).

4. Autonomous Vehicles and AI Robotics: Challenges and Prospects

The advent of autonomous vehicles signifies a substantial leap forward in AI robotics, promising safer transportation with reduced human errors. However, the deployment of these technologies is fraught with challenges, including regulatory hurdles, ethical concerns, and technological limitations such as sensor reliability and data interpretation (Shang et al., 2024). Despite these challenges, the potential benefits, including lower accident rates and increased mobility for underserved populations, underline the importance of advancing these technologies (Ness et al., 2024). Furthermore, as the integration of AI in vehicles evolves, ensuring robust safety measures and addressing public acceptance will be critical for widespread adoption

(Gümüş & Alan, 2025). The integration of AI and robotics across diverse sectors presents promising opportunities for enhancing efficiency, precision, and personalized interactions. However, it is essential to address the distinct challenges posed by each domain, particularly in terms of ethical considerations, regulatory frameworks, and professional training to ensure successful implementation and acceptance of these pioneering technologies.

2.4 Critical Perspectives and Future Directions

As the integration of AI and robotics accelerates across various sectors, ethical and regulatory challenges emerge, necessitating a critical examination of these issues, particularly in fields such as healthcare and hospitality. While, ethical dilemmas associated with AI-enabled robotics are profound and multifaceted. One key aspect is the question of data privacy, particularly concerning patient information in healthcare settings. Reports highlight that a significant barrier to the adoption of AI caregiver robots is the apprehension regarding the disclosure of personal health information by users, linked to concerns about privacy and ethical implications of data use (Amin et al., 2024). Moreover, the intersection of automated systems with human service providers raises questions of accountability, particularly in contexts where decision-making may directly affect human health and well-being (Elendu et al., 2023). The ethics surrounding the deployment of humanoid robots in sensitive environments, such as healthcare and eldercare, further complicates this discourse as it introduces concerns related to emotional engagement and the replacement of human contact with mechanical interactions (Hung et al., 2025). A comprehensive ethical framework is essential for navigating these discussions. Recent studies propose that a set of roboethics principles needs to be developed and enforced to guide the implementation of AI technologies, ensuring that they are utilized responsibly to avoid potential harm to users (Langman et al., 2021). In this context, an ethical strategy would also encompass considerations of fairness and bias in algorithmic decision-making, calling for transparency and rigorous oversight in the development of AI systems (Westerlund, 2020).

Regulatory Challenges and Future Directions

The regulatory landscape for AI-enabled robotics is still evolving and presents another layer of complexity. Prominent studies emphasize the need for a regulatory framework that can adequately address the rapid pacing of technology and the unique challenges posed by autonomous AI systems (Burg et al., 2022). A well-structured regulatory approach can foster innovation while simultaneously safeguarding against ethical violations. Current literature suggests exploring interdisciplinary collaboration to enhance regulatory measures, which could help mitigate risks associated with AI deployments in various sectors (Singh & Singh, 2024; Singh & Singh, 2024). As AI and robotics continue to advance, the future promises significant innovations that can enhance service delivery in healthcare, including surgical applications and telemedicine frameworks designed to improve access while maintaining safety (Bhaskar et al., 2020; Bokhari, 2023). However, such advancements also heighten the importance of ethical considerations. The interplay between autonomous systems and human oversight remains critical, and future studies must focus on establishing guidelines that balance technological innovation with ethical governance to ensure public trust (Ness et al., 2024). Furthermore, the integration of AI robotics in areas such as travel and hospitality indicates a trend where enhanced customer engagement and service efficiency are paramount. This sector particularly raises questions regarding customer perceptions, the role of AI in personal interactions, and the implications for workforce dynamics (Borghi & Mariani, 2021; Koo et al., 2021).

3. Methodology

This study adopts a critical literature review methodology, synthesizing insights from interdisciplinary research on the integration of Artificial Intelligence (AI) and robotics. Unlike empirical investigations based on primary data, the review approach enables an in-depth examination of existing knowledge, trends, and debates surrounding the role of AI in shaping robotics innovation. A critical review is particularly suited to this area of inquiry because the field is rapidly evolving, and fragmented contributions span domains such as manufacturing, healthcare, and education (Ness et al., 2023; Mia & Shuford, 2024). By consolidating these diverse perspectives, the study identifies recurring patterns and contradictions while also uncovering gaps in the scholarly discourse. The methodological process involved three stages. First, relevant peer-reviewed articles, conference proceedings, and reports published within the past five years were identified, with emphasis on works addressing the intersections of AI and robotics in industrial, healthcare, and educational domains (Castro-Inostroza et al., 2024; Hirschmann et al., 2024). Second, a thematic analysis was conducted to extract core issues, including technological contributions, sector-specific applications, and ethical or regulatory challenges (Çağal & Keskin, 2023; Iftikhar et al., 2024). Third, a critical synthesis was applied to juxtapose supportive perspectives emphasizing efficiency and innovation with critical perspectives highlighting risks such as privacy concerns, labor displacement, and uneven adoption. This approach ensures that the review is not merely descriptive but evaluative, engaging with both opportunities and limitations. This methodology is not without limitations. Because it relies on secondary sources, the analysis is shaped by the scope, quality, and availability of existing studies. Moreover, the diversity of contexts (from industrial robotics in manufacturing to socially assistive robots in healthcare) poses challenges for achieving generalizable conclusions (Masala & Giorgi, 2025; Vatkar et al., 2023). Nevertheless, the strength of the approach lies in its ability to highlight converging insights while exposing unresolved tensions in the literature, thereby setting the foundation for future empirical research.

4. Results

The synthesis of the reviewed literature reveals that the integration of Artificial Intelligence (AI) into robotics generates significant benefits across multiple domains while simultaneously raising pressing ethical and socio-economic challenges. The findings are organized into three thematic strands: industrial efficiency, sector-specific applications in education and healthcare, and ethical-regulatory implications. First, in industrial contexts, AI-driven robotics has proven to be a catalyst for smart manufacturing and operational optimization. Several studies demonstrate how predictive maintenance, intelligent quality control, and adaptive learning mechanisms allow industrial robots to autonomously refine processes, thereby increasing efficiency and reducing downtime (Ness et al., 2023; Mia & Shuford, 2024). Importantly, the ability of AI-enabled systems to adapt to dynamic market conditions positions them as critical tools within Industry 4.0 frameworks (Zhu & Wang, 2024). However, critics note that while these benefits are pronounced in technologically advanced economies, the cost of adoption and limited expertise constrain their diffusion in emerging markets, widening global disparities (Charllo, 2024). Second, sector-specific applications highlight how AI-robotics integration is reshaping healthcare and education. In education, interactive robots powered by AI enhance engagement, foster critical thinking, and personalize learning experiences, particularly for younger students (Castro-Inostroza et al., 2024; Zuo et al., 2023). Nevertheless, these innovations risk reinforcing educational inequalities, as well-resourced institutions can implement robotics-based learning more effectively than underfunded schools (Khan et al., 2023). In healthcare, AI-assisted surgical robots such as those described by Hirschmann et al. (2024) enhance precision, reduce errors, and improve recovery outcomes, while AI-driven diagnostics enable earlier disease detection (Vatkar et al., 2023). Despite these benefits, ethical dilemmas around accountability in high-risk decisions and the erosion of patient–doctor relationships remain unresolved challenges. Third, the results underscore persistent ethical and regulatory issues that transcend individual domains. Scholars consistently emphasize that the widespread adoption of AI-enabled robotics necessitates robust frameworks for accountability, transparency, and data privacy (Iftikhar et al., 2024; Vozna & Costantini, 2025). For example, in elder care and socially assistive robotics, concerns about autonomy and emotional dependence raise questions about replacing human contact with mechanical interactions (Masala & Giorgi, 2025). Additionally, barriers such as high implementation costs, insufficient regulatory guidance, and societal skepticism further complicate adoption across industries ("Innovative Applications of AI in Robotics: A Comprehensive Study", 2024; Ness et al., 2024). These findings highlight the dual nature of AI in robotics: while technically transformative, its societal impact is uneven and contested.

Table 1. Summary and Critical Analysis of Reviewed Studies on AI in Robotics

Study / Author(s)	Domain	Key Contributions / Benefits	Limitations / Challenges	Critical Insights
Ness et al. (2023); Mia & Shuford	Industry 4.0 / Manufacturing	Predictive maintenance,	High costs; limited expertise in SMEs	AI-robotics enhances efficiency but

(2024)		automation, improved quality control		adoption is uneven globally
Zhu & Wang (2024)	Industrial applications	Adaptive learning for dynamic optimization	Requires advanced infrastructure	Highlights AI's role in resilient operations
Castro-Inostroza et al. (2024); Zuo et al. (2023)	Education	Interactive, voice-controlled robots enhance engagement and skills	Risk of digital divide in access	Educational robotics fosters problem-solving but may exacerbate inequality
Khan et al. (2023)	Education	Robotics supports critical thinking and creativity	Uneven implementation across institutions	Equity remains a pressing challenge
Hirschmann et al. (2024); Vatkar et al. (2023)	Healthcare / Surgery	Enhanced surgical precision, reduced complications, improved patient outcomes	Ethical issues in accountability; lack of haptic feedback	Robotics improves care quality but raises patient safety dilemmas
Iftikhar et al. (2024); Vozna & Costantini (2025)	Ethical / Social robotics	Accountability, transparency, and privacy highlighted	Ethical dilemmas in elder care, autonomy, and human contact	Need for robust roboethics framework
Masala & Giorgi (2025)	Social / Elder care	Robots provide support and companionship	Emotional dependency, loss of human touch	Raises ethical questions on replacing human interaction
Charllo (2024); "Innovative Applications of AI in Robotics" (2024)	Cross-sector	Policy insights on adoption and diffusion	Regulatory gaps, economic barriers	Collaboration needed between engineers, policymakers, and stakeholders

The findings of this critical literature review are organized into four major themes: industrial efficiency, educational applications, healthcare applications, and ethical-regulatory issues. This structure highlights not only the technological contributions of AI-enabled robotics but also the challenges and contradictions shaping their broader adoption.

1. Industrial Efficiency

In industrial contexts, AI-driven robotics emerges as a cornerstone of Industry 4.0, where intelligent automation redefines operational standards. Research shows that predictive maintenance, advanced quality control, and adaptive learning mechanisms enable robots to continuously optimize processes, thereby increasing efficiency and reducing downtime (Ness et al., 2023; Mia & Shuford, 2024). Moreover, the ability of AI-enabled systems to adapt to fluctuating production demands enhances resilience in competitive markets (Zhu & Wang, 2024). Despite these advantages, adoption remains uneven. Smaller enterprises and organizations in emerging economies face barriers such as high costs, limited expertise, and underdeveloped infrastructure, which hinder widespread deployment (Charllo, 2024). This indicates that while AI enhances efficiency at the industrial frontier, global disparities in adoption persist.

2. Educational Applications

AI-robotics integration is also reshaping the educational landscape. Studies highlight that interactive, voice-controlled robots foster engagement, improve problem-solving skills, and promote critical thinking, particularly among young learners (Castro-Inostroza et al., 2024; Zuo et al., 2023). Robotics in education not only supports STEM learning but also provides opportunities for inclusive teaching methodologies. However, critics warn that access to such technologies remains highly uneven, with well-funded institutions more likely to benefit compared to under-resourced schools (Khan et al., 2023). This creates a digital divide that risks reinforcing inequalities in learning opportunities, suggesting that while AI-driven robotics holds promise for education, equity of access is a pressing issue.

3. Healthcare Applications

Healthcare represents one of the most promising yet ethically complex domains of AI-enabled robotics. Robotic surgical systems demonstrate increased precision, reduced complications, and improved patient recovery outcomes, thereby advancing surgical reliability (Hirschmann et al., 2024). Similarly, AI-driven diagnostic systems facilitate earlier disease detection and more accurate treatment recommendations (Vatkar et al., 2023). Despite these benefits, unresolved challenges persist. Ethical dilemmas around accountability in life-critical procedures, the lack of haptic feedback in robotic surgeries, and concerns over patient–doctor relationships highlight the risks of overreliance on autonomous medical systems. This duality positions healthcare robotics as both a transformative innovation and a field requiring careful governance.

4. Ethical and Regulatory Issues

Beyond sector-specific applications, the most consistent theme in the literature concerns ethical and regulatory challenges. Studies emphasize the urgent need for accountability, transparency, and robust data privacy mechanisms in AI-enabled robotics (Iftikhar et al., 2024; Vozna & Costantini, 2025). In socially assistive contexts such as elder care, scholars highlight concerns over autonomy, emotional dependency, and the replacement of human interaction with robotic companionship (Masala & Giorgi, 2025). Moreover, regulatory frameworks remain underdeveloped, leaving gaps in oversight that exacerbate public skepticism and limit adoption across industries ("Innovative Applications of AI in Robotics: A Comprehensive Study", 2024; Ness et al., 2024). Addressing these ethical and policy challenges is therefore essential to ensuring that the benefits of AI-robotics integration are realized responsibly.

To synthesize these findings, Figure 1 illustrates the conceptual framework derived from the reviewed literature. The model shows how AI technologies drive robotics innovation, which leads simultaneously to benefits (e.g., efficiency, precision, educational engagement) and challenges (e.g., ethical dilemmas, costs, regulatory barriers). These dual outcomes converge to shape broader societal impacts, including labor market transformations, healthcare practices, and the redefinition of educational paradigms.

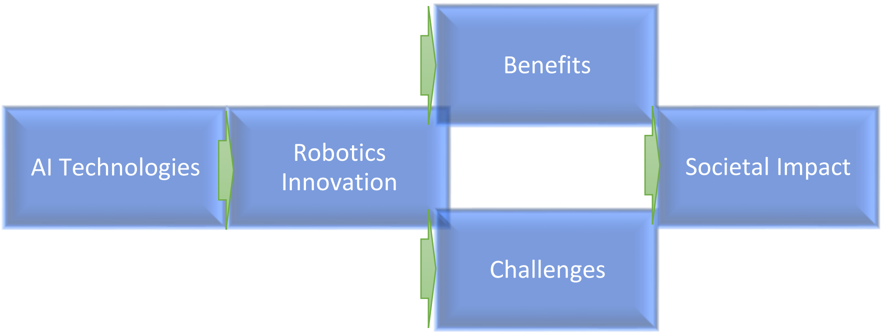

Figure 1. Conceptual Framework: AI and Robotics Innovation

The results demonstrate that AI integration into robotics is both a driver of innovation and a source of contested challenges. Industrial sectors reap clear productivity benefits, yet access remains uneven. Education and healthcare showcase transformative possibilities but risk reinforcing inequalities or raising accountability dilemmas. Ethical and regulatory considerations cut across all domains, underscoring the need for frameworks that ensure transparency, equity, and societal trust. These findings point toward a research gap in balancing technological progress with governance, highlighting that future studies must move beyond technical efficiency to address broader socio-ethical implications.

5. Discussion

The findings of this study highlight the multifaceted role of Artificial Intelligence (AI) in shaping robotics innovation across industrial, educational, and healthcare domains. This discussion critically interprets these results by situating them within broader theoretical debates, reflecting on their implications for practice and policy, and identifying the research gaps that future studies must address. The results confirm that AI-enabled robotics has become a cornerstone of Industry 4.0, enhancing operational efficiency through predictive maintenance, adaptive learning, and intelligent automation (Ness et al., 2023; Mia & Shuford, 2024). These findings resonate with prior research positioning AI as a transformative enabler of industrial competitiveness (Zhu & Wang, 2024). However, a critical tension emerges between advanced economies that benefit from seamless integration and emerging economies where high costs and limited expertise hinder adoption (Charllo, 2024). This disparity illustrates that the technological promise of AI is unevenly distributed, raising questions about global inclusivity in innovation diffusion. From a policy perspective, this underscores the need for frameworks that facilitate technology transfer and skill development in underrepresented regions. In education, AI-driven robotics demonstrates strong potential to enhance teaching methodologies, stimulate student engagement, and develop problem-solving skills (Castro-Inostroza et al., 2024; Zuo et al., 2023). These benefits align with literature highlighting the democratizing potential of robotics in learning environments (Khan et al., 2023). Yet, the review also revealed a risk of reinforcing inequalities, as schools with limited resources are often excluded from robotics-based learning. This finding supports earlier concerns that the "digital divide" may widen if access is not equitably distributed (Zuo et al., 2023). Thus, while AI enhances educational outcomes, its impact is conditional upon resource availability, raising critical questions about equity and inclusivity in educational technology policy. The healthcare sector offers some of the most promising yet ethically contentious applications of AI-enabled robotics. Robotic surgical systems enhance precision, reduce complications, and improve recovery times (Hirschmann et al., 2024; Vatkar et al., 2023). These results confirm prior research emphasizing the medical benefits of AI-assisted interventions. However, the findings also reveal significant ethical challenges, particularly regarding accountability in life-critical procedures and the erosion of trust in patient–doctor relationships (Çağal & Keskin, 2023). This aligns with existing debates in medical ethics, which caution against overreliance on autonomous systems in high-stakes contexts (Iftikhar et al., 2024). Future advancements in healthcare robotics must therefore be accompanied by robust ethical frameworks that safeguard patient safety and ensure human oversight. Across all domains, ethical and regulatory issues emerge as persistent obstacles. Concerns about accountability, transparency, and data privacy are central to debates on AI-enabled robotics (Vozna & Costantini, 2025; Masala & Giorgi, 2025). In socially assistive contexts such as elder care, questions of autonomy, emotional dependency, and the replacement of human interaction underscore the broader societal consequences of robotics adoption (Masala & Giorgi, 2025). Furthermore, the absence of comprehensive regulatory frameworks creates uncertainty for stakeholders and exacerbates public skepticism (Ness et al., 2024). These findings corroborate existing scholarship on roboethics, which calls for principled guidelines to govern AI deployments (Langman et al., 2021). Importantly, this review identifies a gap between technical innovation and ethical governance, suggesting that interdisciplinary collaboration among engineers, ethicists, and policymakers is crucial to bridge this divide. Theoretically, this study contributes to ongoing debates by highlighting the dual nature of AI in robotics: as both a driver of innovation and a source of socio-ethical disruption. It extends Industry 4.0 discourse by situating AI-robotics integration within the context of equity and governance, rather than limiting the discussion to efficiency gains. Practically, the results suggest that organizations adopting AI-enabled robotics must balance technological benefits with social responsibility. For policymakers, the findings emphasize the importance of designing inclusive regulatory frameworks that ensure safe adoption while preventing inequality in access and outcomes. For practitioners, the synthesis underscores the necessity of investing in workforce training, ethical compliance, and participatory design to maximize the benefits of AI-driven robotics.

The review highlights several gaps that future research should address. First, empirical studies examining the long-term societal impacts of robotics adoption remain limited, particularly in education and healthcare. Second, comparative research across regions and industries is necessary to understand the global disparities in adoption and outcomes. Third, future investigations must focus on developing interdisciplinary frameworks that integrate technical innovation with ethical principles and regulatory oversight. Finally, more attention should be given to the voices of end-users—students, patients, and workers—whose perspectives are often marginalized in technologically focused studies. Addressing these gaps will be essential to ensuring that AI-driven robotics evolves in a manner that is both innovative and socially sustainable. Thus, the discussion reveals that AI is both a cornerstone of modern robotics innovation and a catalyst for ethical and societal debates. While the integration of AI enhances efficiency in industry, transforms educational practices, and improves healthcare outcomes, it also introduces challenges related to accountability, privacy, and equity. The dual nature of AI in robotics highlights that technological innovation cannot be divorced from its social context. For AI-enabled robotics to fulfill its transformative potential, stakeholders must prioritize responsible innovation, robust regulation, and inclusive practices.

6. Conclusion

This study has critically examined the role of AI in shaping robotics innovation across diverse sectors, including industry, education, and healthcare. By adopting a literature-based methodology, the research synthesized recent scholarly contributions and identified both the opportunities and challenges associated with AI-enabled robotics. The findings confirm that AI functions as a catalyst for operational efficiency, precision, and adaptability, establishing its significance within the broader trajectory of technological advancement. However, the review also reveals that these benefits are accompanied by persistent challenges. Industrial adoption is hindered by economic and infrastructural disparities, limiting diffusion beyond advanced economies (Charllo, 2024). In education, while AI-robotics enhances student engagement and problem-solving skills (Castro-Inostroza et al., 2024; Zuo et al., 2023), unequal access risks reinforcing the digital divide. Similarly, in healthcare, robotic systems demonstrate transformative potential in surgery and diagnostics (Hirschmann et al., 2024; Vatkar et al., 2023), yet ethical dilemmas concerning accountability and patient trust remain unresolved. Across all domains, regulatory gaps, data privacy issues, and ethical concerns highlight the need for governance frameworks that balance innovation with responsibility (Iftikhar et al., 2024; Vozna & Costantini, 2025). The study therefore concludes that AI-driven robotics embodies a dual character: it is both technically transformative and socially disruptive. Its potential to enhance efficiency, productivity, and service delivery is clear, but its broader societal implications demand careful management. Acknowledging this duality is essential for harnessing the full potential of AI in robotics while ensuring ethical integrity, inclusivity, and long-term sustainability.

This research contributes to existing knowledge in several ways. First, it consolidates fragmented insights across industry, education, and healthcare into a cohesive framework, highlighting common benefits and cross-cutting challenges. Second, it extends discussions on Industry 4.0 by embedding ethical and equity considerations within debates typically dominated by technical efficiency. Third, it identifies critical research gaps concerning governance, inclusivity, and end-user perspectives, thereby providing a roadmap for future inquiry. Collectively, these contributions enrich the discourse on AI-robotics integration by emphasizing that innovation must be understood not only as a technical achievement but also as a socio-ethical endeavour. Building on these findings, several avenues for future research are evident. First, empirical studies are needed to evaluate the long-term societal impacts of AI-enabled robotics, particularly in sensitive contexts such as healthcare and education. Second, comparative cross-country research would provide insights into global disparities in adoption, highlighting how regulatory environments and resource constraints shape outcomes. Third, future work should focus on developing interdisciplinary frameworks that bridge engineering, ethics, and policy, enabling responsible and inclusive innovation. Finally, greater attention must be given to the experiences and perceptions of end-users—patients, students, workers—whose voices remain underrepresented in the literature. Thus, Advancing research in these directions will ensure that AI-driven robotics continues to innovate also does so in a manner that is ethical, inclusive, and socially sustainable.

References

Aggarwal, S. and Professor, A. (2023). Robot learning and adaptation for intelligent behavior.. https://doi.org/10.52783/tojqi.v11i4.10017

Amin, M., Johnson, V., Prybutok, V., & Koh, C. (2024). An investigation into factors affecting the willingness to disclose personal health information when using ai-enabled caregiver robots. Industrial Management & Data Systems, 124(4), 1677-1699. https://doi.org/10.1108/imds-09-2023-0608

Bhaskar, S., Bradley, S., Sakhamuri, S., Moguilner, S., Chattu, V., Pandya, S., … & Banach, M. (2020). Designing futuristic telemedicine using artificial intelligence and robotics in the covid-19 era. Frontiers in Public Health, 8. https://doi.org/10.3389/fpubh.2020.556789

Bokhari, S. (2023). Artificial intelligence and robotics in transplant surgery: advancements and future directions. Cureus. https://doi.org/10.7759/cureus.43975

Borghi, M. and Mariani, M. (2021). Service robots in online reviews: online robotic discourse. Annals of Tourism Research, 87, 103036. https://doi.org/10.1016/j.annals.2020.103036

Burg, S., Giesbers, E., Bogaardt, M., Ouweltjes, W., & Lokhorst, K. (2022). Ethical aspects of ai robots for agri-food; a relational approach based on four case studies. Ai & Society, 39(2), 541-555. https://doi.org/10.1007/s00146-022-01429-8

Çağal, M. and Keskin, Y. (2023). Functional perception of artificial intelligence and robot technology. Sosyolojik Bağlam Dergisi, 4(2), 149-172. https://doi.org/10.52108/2757-5942.4.2.4

Castro-Inostroza, A., Aguilera, C., & Raducanu, B. (2024). Voice-controlled robotics in early education: implementing and validating child-directed interactions using a collaborative robot and artificial intelligence. Applied Sciences, 14(6), 2408. https://doi.org/10.3390/app14062408

Charllo, B. (2024). Ai empowerment in smes: bridging the post-pandemic recovery and innovation gap. Design of Single Chip Microcomputer Control System for Stepping Motor, 3(1), 1-4. https://doi.org/10.47363/jaicc/2024(3)291

Chen, S., Pamungkas, R., & Schmidt, D. (2024). The role of machine learning in improving robotic perception and decision making. International Transactions on Artificial Intelligence (Italic), 3(1), 32-43. https://doi.org/10.33050/italic.v3i1.661

Cheng, M., Li, X., & Xu, J. (2022). Promoting healthcare workers' adoption intention of artificial-intelligence-assisted diagnosis and treatment: the chain mediation of social influence and human–computer trust. International Journal of Environmental Research and Public Health, 19(20), 13311. https://doi.org/10.3390/ijerph192013311

Cruz, E., Oliveira, S., & Correia, A. (2024). Robotics applications in the hospital domain: a literature review. Applied System Innovation, 7(6), 125. https://doi.org/10.3390/asi7060125

Elendu, C., Amaechi, D., Elendu, T., Jingwa, K., Okoye, O., Okah, M., … & Alimi, H. (2023). Ethical implications of ai and robotics in healthcare: a review. Medicine, 102(50), e36671. https://doi.org/10.1097/md.0000000000036671

Giansanti, D. (2025). Advancements and impacts of assistive technologies, robotics, and automated machines in healthcare: insights from an editorial initiative of exploration. Healthcare, 13(10), 1121. https://doi.org/10.3390/healthcare13101121

Glauser, R., Holm, J., Bender, M., & Bürkle, T. (2023). How can social robot use cases in healthcare be pushed - with an interoperable programming interface. BMC Medical Informatics and Decision Making, 23(1). https://doi.org/10.1186/s12911-023-02210-7

Gümüş, E. and Alan, H. (2025). Perspectives of physicians, nurses, and patients on the use of artificial intelligence and robotic nurses in healthcare. International Nursing Review, 72(2). https://doi.org/10.1111/inr.70017

Hernández, A., Ortega-Mendoza, R., Villatoro-Tello, E., Camacho-Bello, C., & Pérez-Cortes, O. (2024). Natural language understanding for navigation of service robots in low-resource domains and languages: scenarios in spanish and nahuatl. Mathematics, 12(8), 1136. https://doi.org/10.3390/math12081136

Hirschmann, M., Eisenhart-Rothe, R., Graichen, H., & Zaffagnini, S. (2024). Ai may enable robots to make a clinical impact in total knee arthroplasty, where navigation has not!. Journal of Experimental Orthopaedics, 11(4). https://doi.org/10.1002/jeo2.70061

Hung, L., Abdulai, A., Soni, A., Wong, K., Ren, H., Xia, R., … & Davies, K. (2025). Students perspectives on the development and deployment of an ai-enabled service robot in long-term care. Journal of Rehabilitation and Assistive Technologies Engineering, 12. https://doi.org/10.1177/20556683251313773

Ibuki, T., Ibuki, A., & Nakazawa, E. (2023). Possibilities and ethical issues of entrusting nursing tasks to robots and artificial intelligence. Nursing Ethics, 31(6), 1010-1020. https://doi.org/10.1177/09697330221149094

Iftikhar, M., Saqib, M., Zareen, M., & Mumtaz, H. (2024). Artificial intelligence: revolutionizing robotic surgery: review. Annals of Medicine and Surgery, 86(9), 5401-5409. https://doi.org/10.1097/ms9.0000000000002426

Khan, S., Chowdhury, M., & Nandy, U. (2023). Ai robotics technology: a review. Journal of Engineering Research and Reports, 25(10), 187-194. https://doi.org/10.9734/jerr/2023/v25i101011

Knudsen, J., Ghaffar, U., Ma, R., & Hung, A. (2024). Clinical applications of artificial intelligence in robotic surgery. Journal of Robotic Surgery, 18(1). https://doi.org/10.1007/s11701-024-01867-0

Koo, C., Xiang, Z., Gretzel, U., & Σιγάλα, M. (2021). Artificial intelligence (ai) and robotics in travel, hospitality and leisure. Electronic Markets, 31(3), 473-476. https://doi.org/10.1007/s12525-021-00494-z

Koubâa, A., Ammar, A., & Boulila, W. (2024). Next-generation human-robot interaction with chatgpt and robot operating system. Software Practice and Experience, 55(2), 355-382. https://doi.org/10.1002/spe.3377

Lan, X., Y, H., & Cui, L. (2022). Application of telemedicine in covid-19: a bibliometric analysis. Frontiers in Public Health, 10. https://doi.org/10.3389/fpubh.2022.908756

Langman, S., Capicotto, N., Maddahi, Y., & Zareinia, K. (2021). Roboethics principles and policies in europe and north america. Sn Applied Sciences, 3(12). https://doi.org/10.1007/s42452-021-04853-5

Lareyre, F., Wanhainen, A., & Raffort, J. (2023). Artificial intelligence–powered technologies for the management of vascular diseases: building guidelines and moving forward evidence generation. Journal of Endovascular Therapy, 32(3), 541-544. https://doi.org/10.1177/15266028231187599

Li, C. (2024). A review of identity and roles of robotics in the healthcare industry. Journal of Biomedical and Sustainable Healthcare Applications, 22-32. https://doi.org/10.53759/0088/jbsha20240403

Luo, R., Zhang, T., Chen, D., Hoorn, J., & Huang, S. (2022). Social robots outdo the not-so-social media for self-disclosure: safe machines preferred to unsafe humans?. Robotics, 11(5), 92. https://doi.org/10.3390/robotics11050092

Masala, G. and Giorgi, I. (2025). Artificial intelligence and assistive robotics in healthcare services: applications in silver care. International Journal of Environmental Research and Public Health, 22(5), 781.

https://doi.org/10.3390/ijerph22050781
Mia, M. and Shuford, J. (2024). Exploring the synergy of artificial intelligence and robotics in industry 4.0 applications. JAIGS, 1(1). https://doi.org/10.60087/jaigs.v1i1.31
Miao, K., Chen, C., & Zheng, X. (2023). A study on the application of artificial intelligence in the design of intelligent medical robots. Applied Mathematics and Nonlinear Sciences, 9(1). https://doi.org/10.2478/amns.2023.2.01388
Molfino, R., Cepolina, F., Cepolina, E., Cepolina, E., & Cepolina, S. (2023). Robots trends and megatrends: artificial intelligence and the society. Industrial Robot the International Journal of Robotics Research and Application, 51(1), 117-124. https://doi.org/10.1108/ir-05-2023-0095
Ness, S., Shepherd, N., & Xuan, T. (2023). Synergy between ai and robotics: a comprehensive integration. Asian Journal of Research in Computer Science, 16(4), 80-94. https://doi.org/10.9734/ajrcos/2023/v16i4372
Ness, S., Xuan, T., & Oguntibeju, O. (2024). Influence of ai: robotics in healthcare. Asian Journal of Research in Computer Science, 17(5), 222-237. https://doi.org/10.9734/ajrcos/2024/v17i5451
Nishad, A., Wafgaonkar, A, & Singh, D. (2024). Innovative applications of ai in robotics: a comprehensive study. International Journal of Progressive Research in Engineering Management and Science. https://doi.org/10.58257/ijprems36234
Osman, E., Ismail, M., Mukhtar, M., Ahmed, A., Mohamed, N., & Ibrahim, A. (2025). Artificial intelligence and robotics in minimally invasive and complex surgical procedures: a systematic review. Cureus. https://doi.org/10.7759/cureus.81339
Pushpan, P. and P, C. (2024). The integration of robotics in surgery: advancements, challenges, and future prospects. South Eastern European Journal of Public Health, 2215-2221. https://doi.org/10.70135/seejph.vi.2355
Rivero-Moreno, Y., Rodriguez, M., Losada-Muñoz, P., Redden, S., Lopez-Lezama, S., Vidal-Gallardo, A. & Teran-Quintero, S. (2024). Autonomous robotic surgery: has the future arrived?. Cureus. https://doi.org/10.7759/cureus.52243
Shang, Z., Chauhan, V., Devi, K., & Patil, S. (2024). Artificial intelligence, the digital surgeon: unravelling its emerging footprint in healthcare – the narrative review. Journal of Multidisciplinary Healthcare, Volume 17, 4011-4022. https://doi.org/10.2147/jmdh.s482757
Singh, K. and Singh, P. (2023). Machine learning in robotics with fog/cloud computing and iot. Eai Endorsed Transactions on Ai and Robotics, 2. https://doi.org/10.4108/airo.3621
Singh, K. and Singh, P. (2024). Fog cloud computing and iot integration for ai enabled autonomous systems in robotics. Eai Endorsed Transactions on Ai and Robotics, 3. https://doi.org/10.4108/airo.3617
Singh, P. and Singh, K. (2024). Interdisciplinary approaches: fog/cloud computing and IOT for ai and robotics integration. Eai Endorsed Transactions on Ai and Robotics, 3. https://doi.org/10.4108/airo.3620
Sodiya, E., Umoga, U., Amoo, O., & Atadoga, A. (2024). Ai-driven warehouse automation: a comprehensive review of systems. GSC Advanced Research and Reviews, 18(2), 272-282. https://doi.org/10.30574/gscarr.2024.18.2.0063
Stella, F., Hughes, J., Rus, D., & Santina, C. (2023). Prescribing cartesian stiffness of soft robots by co-optimization of shape and segment-level stiffness. Soft Robotics, 10(4), 701-712. https://doi.org/10.1089/soro.2022.0025
Sun, S., Ye, H., & Law, R. (2024). A scoping review of robotic technology in hospitality and tourism. Journal of Hospitality and Tourism Technology, 16(2), 286-304. https://doi.org/10.1108/jhtt-08-2023-0247
Tsur, E. and Elkana, O. (2024). Intelligent robotics in pediatric cooperative neurorehabilitation: a review. Robotics, 13(3), 49. https://doi.org/10.3390/robotics13030049
Vatkar, A., Shinde, S., Kale, S., & Bhor, P. (2023). Recent advances in spine surgery- pros and cons. Journal of Clinical Orthopaedics, 8(2), 50-53. https://doi.org/10.13107/jcorth.2023.v08i02.596
Vozna, A. and Costantini, S. (2025). Ethical, legal, and societal dimensions of ai-driven social robots in elderly healthcare. Intelligenza Artificiale. https://doi.org/10.1177/17248035241310192
Wang, X. (2024). Development analysis of intelligent robots in manufacturing industry. Applied and Computational Engineering, 31(1), 207-217. https://doi.org/10.54254/2755-2721/31/20230152
Westerlund, M. (2020). An ethical framework for smart robots. Technology Innovation Management Review, 10(1), 35-44. https://doi.org/10.22215/timreview/1312
Yow, J., Garg, N., Ramanathan, M., & Ang, W. (2024). Extract – explainable trajectory corrections for language-based human-robot interaction using textual feature descriptions. Frontiers in Robotics and Ai, 11. https://doi.org/10.3389/frobt.2024.1345693
Zhao, C., Yuan, S., Jiang, C., Cai, J., Yu, H., Wang, M., … & Chen, Q. (2023). Erra: an embodied representation and reasoning architecture for long-horizon language-conditioned manipulation tasks. Ieee Robotics and Automation Letters, 8(6), 3230-3237. https://doi.org/10.1109/lra.2023.3265893
Zhu, Y. and Wang, S. (2024). Research on the influence of industrial intelligence on the activity of innovation and entrepreneurship. International Business & Economics Studies, 6(3), p20. https://doi.org/10.22158/ibes.v6n3p20
Zuo, Y., Che, L., & Zhang, L. (2023). The development of robotics courses for young children under vector space model. Plos One, 18(10), e0293397. https://doi.org/10.1371/journal.pone.0293397