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The Future of Humanoids in Society: Capabilities and Integration into Human Environments with an Emphasis on Healthcare

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Abstract

Humanoid robots are increasingly being explored for use in human-centered environments, particularly in healthcare, where aging populations, workforce shortages, and growing demands for physical assistance present ongoing challenges. Despite the recent advances in artificial intelligence, sensing, and actuation, there remains a gap between experimental performance and reliable deployment in real-world settings. This review examines the current state of humanoid robotics with an emphasis on applications requiring physical interaction and adaptability. Relevant literature was analyzed to evaluate progress in sensory-motor integration, locomotion, manipulation, and autonomy, along with key factors influencing human-robot interaction, including trust, safety, and ethical considerations. Current evidence suggests that humanoid robots demonstrate strong performance in controlled environments and show promise in rehabilitative and assistive roles. However, limitations in generalizability, robustness, and long-term reliability continue to restrict their use in unstructured, real-world contexts. In healthcare settings, these constraints are further compounded by high safety requirements and the need for consistent, predictable behavior. Overall, the current literature indicates that near-term deployment is most feasible through gradual, task-specific integration and hybrid human-robot collaboration rather than full autonomy. Humanoid robots are more likely to augment human capabilities than replace them, specifically in repetitive or physically demanding tasks. Future progress will depend not only on technical improvements but also on ethical oversight, regulatory development, and alignment of system capabilities with user expectations.

Keywords

Humanoid Robots, Clinical Robotics, Human-Robot Interaction, Artificial Intelligence, Rehabilitation Robots, Healthcare Technology, Assistive Robotics

1. Introduction

Due to growing demands for rehabilitation and physical assistance, workforce shortages, and an aging population, human environments such as homes, hospitals, clinics, and workplaces are facing increasing challenges. The presence of robotics in human-centered environments has been limited by challenges in safety, adaptability and physical interaction, even though they have long been used in industrial settings. However, with recent advances in artificial intelligence, sensing, and actuation, people have started to renew their interest in humanoid robots, robots that are designed with human-like form and movement capabilities. In this review, humanoid robots are defined as systems that possess a human-like physical morphology, including a head, torso, and limbs, enabling them to perform tasks within environments designed for human use. This definition includes semi-humanoid service robots and socially assistive robots that exhibit partial human-like features or interaction capabilities, but excludes wearable robotic systems such as exoskeletons, as they do not operate as independent agents; however, such systems may be referenced where relevant for comparison or to contextualize rehabilitation applications. Humanoid robots are created to operate in settings that require physical interaction and situational awareness, different from traditional robots, which often perform repetitive tasks in isolated settings.

Even though workspaces, rehabilitation centers and hospitals have only recently started to integrate humanoid robots into their environments, technological progress and evolving public perception are making their integration more practical. These robots have the potential to provide valuable support in settings where extra assistance is needed and to increase human productivity. It is important to maintain objectivity and carefully evaluate both their current limitations and their realistic long-term roles as their abilities expand.

The goal of this review is to identify the current state of humanoid robotics, evaluate their capabilities and restrictions, and explore potential future roles in human centered environments, with a special focus on healthcare settings where safety and physical interaction are necessary. By blending current research and new trends, the review aims to provide a balanced perspective on the opportunities and challenges of integrating humanoid robots into society, with implications for future clinical and rehabilitative applications. Throughout the remainder of this review, humanoid robots will be referred to simply as humanoids.

2. Materials and Methods

This narrative review examines recent developments in humanoid robotics, with a focus on applications in healthcare and human-centered environments. Relevant literature was identified through searches of databases including PubMed, and Google Scholar using combinations of keywords such as "humanoid robots," "human-robot interaction," "rehabilitation robotics," "assistive robotics," "clinical robotics," and "robotic locomotion." Boolean operators (AND, OR) were applied to refine the search strategy. The search was conducted primarily for studies published between 2010 and 2025, with earlier foundational studies included where relevant. Articles were selected based on their relevance to key areas including locomotion, sensory-motor systems, autonomy, and clinical applications. Inclusion criteria consisted of peer-reviewed articles written in English that focused on humanoid or semi-humanoid robotic systems and their applications in human-centered or clinical environments. Exclusion criteria included studies focusing solely on industrial robots, non-robotic assistive devices, or wearable systems such as exoskeletons unless used for contextual comparison. Both primary studies and review articles were considered. The screening process involved an initial review of titles and abstracts to assess relevance, followed by a full-text evaluation of selected articles to confirm eligibility based on the defined criteria. No statistical analysis was performed, and ethical approval was not required, as this study did not involve human or animal subjects.

3. Results

The findings of this review are organized into key thematic areas reflecting the current capabilities, limitations, and applications of humanoid. These areas are presented in the following sections.

3.1. Current State of Humanoids

Current humanoids show increasingly advanced locomotion capabilities, specifically in bipedal movement. To enable stable and repeatable gait patterns, walking on flat and structured surfaces has been thoroughly studied and largely mastered through model-based control methods using periodic motions [1], although performance remains less reliable on uneven, deformable, or unpredictable terrain. These approaches have also expanded beyond basic walking to more vigorous behaviors such as running, jumping, and even back-flipping. Similarly, learning-based methods have proven highly effective for bipedal locomotion, they also enable the robots to handle more complex and non-periodic motions, such as climbing the stairs, and parkour [1], though these behaviors often require extensive training data and may not generalize consistently across new environments. Along with their progress in locomotion, humanoids have also made notable progress in hand manipulation and dexterity. To closely mimic the structure and motion of the human hand, modern humanoid systems employ five-fingered dexterous hands with over 20 DoF (degrees of freedom) [2], but fine manipulation of small, fragile, or deformable objects remains challenging. Their human-like appearance and behavior can improve social acceptance in domains such as healthcare and service settings. This level of sophistication also allows them to adapt to human-centered environments and handle complex tools [2], but often requires structured conditions and task-specific tuning.

Since their anthropomorphic form enables them to execute whole-body loco-manipulation tasks similar to those performed by humans, humanoids are particularly well suited for navigating human-designed environments and structures [1], though navigation performance can degrade in cluttered or dynamically changing settings. These abilities allow them to support a wide range of applications, from manufacturing to service work. These applications also include physical collaboration with humans such as cooperatively moving heavy objects or assisting with mobility related tasks [1], but safe and efficient coordination still depends heavily on controlled interaction protocols and limited variability in human behavior. However, due to the complexity of humanoid dynamics and the difficulty of ensuring reliable human-robot interaction, especially outside of structured settings, safely achieving these human-humanoid coordination remains challenging [1].

In terms of deployment, humanoids or humanoid-like systems are already present in rehabilitation and healthcare related settings. For example, they are often used in the form of wearable robotic devices and exoskeletons, designed to restore or improve walking performance [3]. They are increasingly adapting to individual users through biofeedback driven control and have been applied to patients with neurological disorders or lower-limb amputations [3], although outcomes can vary based on patient condition, system calibration, and clinical supervision. Using expressive joint, head, and facial movements to support a more engaging human-to-humanoid interaction, humanoids are tasked with therapist-guided interventions, psychological testing, and mental health promotion within these environments, in which they have demonstrated success [4], though their effectiveness is often limited to structured therapeutic scenarios and short-term interactions. Finally, patient acceptance can also be considered a boundary since no matter how efficient and how effectively they mimic human behavior, without acceptance, it will be difficult for them to be integrated in a rehabilitation setting (see section 4.1).

Despite the substantial progress, significant limitations still restrict the broader deployment of humanoids. As AI-driven humanoid systems move beyond controlled industrial environments into everyday human settings, safety becomes a critical concern encompassing the reliability of control systems, cybersecurity, software robustness, and safe physical interaction [5]. Current safety standards and regulations often lag behind the rapid technological advances, while ethical and societal factors further complicate adoption [5]. These challenges are even more prominent in unstructured or semi-structured environments such as disaster response scenarios, where unpredictable lighting, terrain, and limited data reduce the system's reliability [6]. Nonetheless, humanoids continue to be considered for human-designed environments because their human-like form allows them to operate within spaces and workflows built for humans with minimal-to-no modifications [7], although this advantage does not eliminate the need for environmental adaptation or task-specific optimization. Compared to task-specific robots, humanoids with their human-like appearance, can foster greater comfort and trust among users while also offering the potential to perform a wide range of tasks without needing multiple specialized machines. However, for humanoids to be widely deployed, their key capabilities still need improvement, including robust handling of unexpected situations, longer battery life to support full work shifts, and more natural, innate interaction with humans [8]. Addressing these challenges remains essential to make humanoids reliable, practical and economically reasonable at scale [9].

3.2. Sensory and Motor Foundations of Humanoids

To perceive and interact with their surroundings, humanoids use a combination of sensory modalities, most commonly vision, audio, and touch. Together, these systems allow the robots to gather information about their own body state, nearby objects, environmental structure, and human activity, forming the foundation for task execution and interaction [6]. Visual perception is particularly central among all of the sensory modalities. To operate autonomously rather than executing a set of predefined instructions, vision sensors are essential. They enable humanoids to perceive layouts, identify objects, and localize themselves within an environment [10]. By enabling spoken communication, audio perception further supports interaction. Humanoids can interpret verbal commands and respond accordingly through speech recognition and natural language processing, which are important when they are deployed in human-centered environments [11]. Tactile sensing ties all the modalities together by providing direct physical feedback during contact. This allows humanoids to manipulate objects in situations where vision and audio perception alone may not be enough [12].

Even with the significant progress of the current research, robotic sensing still fails to meet the dexterity and adaptability of human sensing that is required to perform complex manipulation and locomotion tasks [13]. Through internal representations of the humanoid's body, also known as body schemas, sensory inputs are coupled with motor control to address these inabilities. To estimate limb position and guide movement, these internal models integrate proprioceptive feedback with visual predictions, this enables closed-loop regulation strategies such as accurate reaching [14]. Constantly updating these internal estimates based on the sensory feedback allows robots to reduce errors and improve movement precision.

However, perception is only one part of the whole control process. Before actions are executed, sensory information must be acknowledged and translated into decisions. To be able to behave effectively, humanoids need to be able to perceive human intent and environmental context, select an appropriate response, and then coordinate their movement accordingly [15]. This is why humanoid motion should not be viewed as purely mechanical, as even the most basic locomotion patterns require computation, prediction and feedback to maintain the humanoid's balance and adapt to disturbances in real time [16]. These capabilities are commonly structured through hierarchical control architectures. In these cases, high-level planning defines the goal of the task, while low-level controllers maneuver the detailed motor execution [17]. Together, these sensory and motor mechanisms would allow humanoids to function in human-centered environments, a gap remains between humanoid systems and human perception.

3.3. Autonomy, Learning, and the Question of "Conscious" Humanoids

Apart from physical incorporation, a challenge for humanoid deployment is their inability to rapidly and reliably understand their environment, process information, and produce prompt action, particularly when there are no step-by-step or direct instructions [18]. Despite these challenges, modern humanoids operate through internal models and learned control programs, deciding the action based on goals, sensory input and environmental restrictions, instead of relying on predetermined scripts.

In humanoids, an absence of explicit instruction does not imply a lack of structure, but rather their ability to evaluate their environment, perceive and respond to the different scenarios of everyday life. Systems that aren't based on predefined scripts prioritize contextual reasoning, situational awareness, and ethical decision-making. Using these human-like traits, humanoids emphasize safe and effective operation in complex, real-world scenarios [19]. To support this form of autonomy, humanoids rely on different methods. These methods include learning based frameworks such as active inference which combines other frameworks such as state estimation, control and world model learning [20]. In these frameworks, internal models play a crucial role, these internal models help integrate sensory and motor information to humanoids which in return enables them to be able to predict and motor plan through internal simulation. These internal models, with adaptive and predictive methods, are what distinguish humanoid from traditional robots, which lack the flexibility needed for human-centered environments.

Humanoid behavior can be modified through learning from prior data or through real-time ongoing sensory feedback. Online learning allows humanoids to interact with their environments and update their flow of information as new data and feedback become available. On the other hand, offline learning refers to training the data using static, pre-collected datasets without any access to the environment during training [21]. While offline learning supports efficient data collection, online learning enables humanoids to adapt during deployment rather than relying only on pre-trained behaviors. Imitation learning, in which humanoids acquire new skills by observing human behaviors is a practice humanoids use during interaction with their environments and users, making this approach especially effective for learning mobility [21]. When operating in frequently changing environments and system conditions, humanoids rely on adaptive control and predictive models to maintain performance [22]. As human-centered environments can be uncertain and constantly changing, this real-time adaptability is essential for safe operation [23].

Structurally, humanoids operate through a perception-processing-action loop that converts sensory input into coordinated motor output [24]. They typically incorporate multiple sensory techniques to perceive and interact with their environment [25]. To overcome individual limitations and improve environmental understanding, the sensory information is integrated through sensory fusion which combines data from multiple sensors [26]. This loop covers prediction, inference, planning, and learning, enabling robots to interpret sensory data, select actions, and generate coherent behavior [15]. However, in some cases, noise and uncertainty can lead to incorrect state estimation, affecting decision-making and control of the humanoid. To address this issue, humanoids employ probabilistic state estimation methods that model noise and repeatedly update beliefs based on incoming observations [27].

Humanoids must use body language such as gestures, facial expressions, and body postures to communicate their intent, control attention, resolve ambiguity and convey emotional states, which are beyond just joint actuation. As a result, humanoids are designed to function in human environments, use human tools and interact through natural communication channels [28]. This ability shows the shift in humanoid investigations from mechanically focused studies to modern research environments with an emphasis on cognition and adaptability. Human-aware motion planning, which forecasts human action and adjusts robot routes to avoid conflicts in shared workplaces is essential for humanoids to operate safely alongside humans [29]. Along with motion-planning strategies, feedback is used in shaping motor control as it enables them to recover from disturbances, enhances their robustness and provides them with human-like movements with simple control architectures [30].

People often assume that humanoids are "conscious," even though consciousness itself is a difficult term to define. Even though humans do not fully understand or agree on how human consciousness occurs, it becomes easy to project these "conscious" qualities onto machines that look or behave like humans [31]. This is part of the reason why researchers make a clear distinction between cognition and consciousness. Consciousness involves higher levels of self-awareness and monitoring while cognition refers to information processing [31]. Being able to comprehend the difference between cognition and consciousness matters in healthcare and social settings, primarily because it helps people set realistic expectations about what tasks humanoids are capable of performing. From a practical standpoint, it is irrelevant for the humanoid to be conscious as long as it has the cognitive ability to perform its assigned activities. These distinctions become even more critical in clinical settings, where humanoid adaptability is essential, as healthcare professionals and systems are constantly adjusting to changing demands, unexpected situations, and limited resources [32]. At the same time, mistakes in a humanoid's perception or learning can create risks, and human trust depends on predictability, so people need robots that they can "trust" and that act consistently and as expected [33], reinforcing the importance of clearly defined role boundaries in which humanoids support rather than replace clinical decision-making. Rather than genuine conscious awareness, some theories suggest that most current robotic systems only replicate unconscious background processes [31]. This concept is revealed more clearly in humanoid designs that are inspired by human thinking. The system has many specialized parts, working at the same time to produce the most important information [31].

3.4. Levels of Human-Robot Interaction

Human-Robot Interaction (HRI) can be defined as a continuum in which control and responsibility are distributed between humans and humanoids. This spectrum encompasses teleoperation that requires constant human input, to fully autonomous humanoids operating independently without any human intervention [34]. The required human interaction for the core functions of sensing, planning, and action decreases as a humanoid gains more autonomy. These core functions can be assigned to either the human, or the humanoid, or both [35]. During interaction, as humans become more aware of the humanoid's perceptual and processing limitations, they naturally adapt their communication tactics. Humans tend to adjust word choice, speech length, and prosody to better communicate with their partnered humanoid [36]. These adaptations from both sides of the interaction emphasize the dynamic nature of HRI and confirm that it's not a one-sided process.

Because of their human-like appearance and long-standing cultural imagery, humanoids are subject to exceptionally high public expectations, including assumptions of broad adaptability and seamless integration into human environments [8]. In reality, even though humanoids often display impressive technical skills, their real-world deployment is still restricted by reliability, scalability, and economic sustainability. To bridge this gap between humanoids and human-centered environments, trust plays a crucial role. Research shows that people tend to trust humanoids more when they most closely resemble humans both in behavior and appearance, such as voice, gestures, facial features, and social cues [37]. Interaction quality further influences comfort and acceptance. Humanoids that behave more politely are rated as more acceptable, with appearance and behavior contributing independently to user perception [38]. Overall, however, long term trust depends more on consistent behavior rather than exact replication of human appearance. Dependable and predictable robot behavior allows users to build trust and anticipate actions, whereas irregular behavior undermines trust [39].

As human-humanoid interaction becomes more advanced, ethical concerns will continue to grow [40]. When robots inherit human biases through their programming or when excessive human qualities are attributed to machines, issues such as discrimination, dehumanization, and deception arise. Humanoids caring for elderly patients may deceive them by creating the illusion of companionship and emotional understanding, even though the humanoid does not possess genuine feelings or concern. This simulated relationship may exploit vulnerable individuals and cause more harm than good [41]. Technologies perceived as useful and compatible are far more likely to gain acceptance than those seen as unnecessary or disruptive, so beyond ethics, public questions whether humanoids should be adopted at all will increase [42]. Therefore, managing expectations is critical for responsible deployment. Aligning humanoid performance with clearly communicated capabilities prevents disappointment and allows trust to develop based on real evidence rather than excessive promises [43].

4. Discussion

4.1. Integration into Society and Workplaces

Humanoid or humanoid-like robots are increasing their presence in healthcare environments, including being deployed in a range of clinical tasks [44]. In some hospitals, semi-humanoid robots are tasked to deliver medications, transport lab samples, and navigate elevators, reducing the routine burdens on staff [45]. In clinical roles, like rehabilitation, AI-assisted humanoids accompany human therapists rather than replacing them completely. These humanoids allow clinicians to dedicate more time to complex, individualized patient care while they perform repetitive procedures [44]. Rehabilitation humanoids in particular, assist patients recovering from stroke, mobility impairments or other health conditions by guiding exercises, and facilitating daily activities under the supervision of a human professional [46]. Even with substantial advancements, practical restrictions still arise, such as limited battery life, poor manipulation of everyday objects, and unstable balance, which challenge the integration of humanoids into human-centered environments [47]. Especially in clinical contexts, safety and reliability are critical. Regulatory and ethical considerations, such as accountability, transparency, privacy, fairness, and preservation of human autonomy, must be addressed to maintain trust and comply with healthcare standards [48].

Initially, humanoids are most likely to be deployed in controlled environments, such as retail, industrial, and service settings where layouts are predictable, rather than complex settings like hospitals. They can be tasked with simpler chores like sorting or tray delivery [49]. Realistically, fully autonomous humanoids remain a long-term objective; on the other hand, hybrid human-robot systems are currently more practical. They combine human situation awareness, corrective actions, and contextual decision making with robotic precision and repeatability [50]. Rather than rapid large-scale deployment, gradual integration of the humanoid enables safer and more effective adaptation in workplaces [51]. In healthcare settings, different levels of autonomy are more appropriate for different task types. Tasks that require high precision and accountability, such as surgical assistance of complex patient handling, are best suited for teleoperation or direct human control. Routine and repetitive tasks, including medication delivery, sample transport, or basic rehabilitation guidance, can be performed under supervised autonomy, where humanoids operate independently but remain under human oversight. More complex and dynamic interactions, such as patient engagement, mobility assistance, or therapy support, are better suited for hybrid human-robot workflows that combine robotic consistency with human judgment and adaptability. This task-based distribution of autonomy helps balance efficiency, safety, and trust in clinical environments. Collectively, all of these developments underline a realistic path for humanoids in which they can enhance human labor, and expand their social role without abandoning up safety, ethics, or practical feasibility.

4.2. Perceptions and Adaptation Readiness of Humanoid in Healthcare

Successful integration of humanoid into healthcare environments depends not only on technical capability and regulatory approval, but also on the attitudes and readiness of healthcare professionals. Survey-based research indicates that healthcare stakeholders generally report cautiously positive attitudes toward humanoid and socially assistive robots, though acceptance varies depending on familiarity with technology, prior exposure, and professional background [52]. Ethical acceptability, perceived usefulness in clinical workflows, and clarity of the humanoid robot's role in supporting, rather than replacing, healthcare staff, consistently emerge as central factors shaping perception [53].

Beyond general attitudes, psychological predictors play a significant role in adoption readiness. Confidence in one's ability to use robotic systems, often conceptualized as robot-use self-efficacy, is strongly associated with both functional and social acceptance among care professionals, suggesting that perceived competence may directly influence willingness to integrate robotic technologies into practice [54]. Additionally, structured exposure to robotic systems has been shown to positively influence trust and acceptance, with interactive demonstrations producing stronger shifts in perception than passive forms of exposure [55]. Behavioral intention models further support this pattern, indicating that positive attitudes and perceived behavioral control significantly predict intention to engage with humanoids in healthcare settings [56].

Collectively, these findings suggest that the adoption of humanoids in clinical environments is a socio-cognitive process shaped by familiarity, self-efficacy, trust, and ethical evaluation. As such, effective integration strategies may require not only technical refinement but also targeted education, demonstration opportunities, and expectation management to foster sustainable acceptance among healthcare professionals.

4.3. Challenges and Open Questions

Humanoids often struggle to maintain reliability during real-world deployment despite their impressive exhibition in laboratory settings. This is primarily because their sensing, perception, and control systems are validated under controlled environments that often fail to capture the variability and unpredictability of dynamic real-world settings such as changing lighting, clutter, and moving people [57]. These reliability issues are largely related to fundamental limits in skill generalization, as even generalist robots, trained on large-scale datasets tend to perform poorly outside the distribution of their training data, which makes adaptation to novel tasks, environments and users difficult [57]. Overall, the failures of these humanoids in real world robustness are not only because of technical glitches but systemic limitations in how humanoid skills are learned and transferred. Augmenting these challenges, increasing autonomy in humanoids introduces critical trade-offs with safety and controllability. Higher levels of autonomous decision making can elevate risk, which in turn decreases operational flexibility. These risk factors need to be constrained by compliance mechanisms, fault-tolerant control, or human oversight to ensure fail-safe operation [5]. This tension demonstrates why fully autonomous humanoids remain difficult to deploy safely in unstructured, human-centric environments.

These technical challenges become even more prominent in clinical and rehabilitation settings, where humanoids must adapt to unpredictable workflow, diverse patient needs, and high safety expectations, while regularly lacking the adaptability, robustness, and dependability required for permanent integration [58]. Social and perceptual barriers further hinder adoption such as concerns about the dehumanization of care, and limited interactive skills. and negative presumptions toward robots in healthcare [59]. Along with social barriers, user trust remains a central challenge. As discussed earlier, trust in humanoids depends less on technical capability and more on predictable behavior, expectation alignment, and consistency. When humanoids fail to meet these expectations, confidence in human-humanoid interaction can quickly deteriorate [60]. These unresolved technical, clinical, and socio-cognitive challenges highlight why slow, expectation-aware integration of humanoids remains necessary as the field moves toward broader real-world deployment.

4.4. Future Outlook: Bridging Expectation and Capability

Looking forward, near-term progress in humanoids is most likely to emerge in areas such as more efficient actuation, improved structural design, advanced materials, and safer control architectures. More progressive goals such as human-level dexterity, adaptability and energy efficiency remain a long-term research challenge [47]. Insights from brain-inspired intelligence, bionics, mechanics, and control offer a promising path for gradual advancements rather than sudden breakthroughs, supporting the importance of interdisciplinary development [47]. Similarly, in workplace settings, gradual and task-specific integration of humanoids appears more plausible than broad replacement, as they can enhance human labor by handling physically demanding, repetitive, or hazardous tasks while humans take on more complex and higher-level roles [61]. This enhancement model also ensures that humans remain essential within increasingly automated environments by taking on new human-centered roles such as supervision, collaboration, and training [61].

In settings like healthcare, rehabilitation and assisting, humanoids are most likely to contribute to supportive capacities. This involves monitoring patient movements during therapy, assisting with repetitive rehabilitation exercises, and supporting patient engagement during recovery [62]. As these systems become highly embedded in everyday life, robust safeguards will be essential. These safeguards include redesigned risk assessment methodologies, control architectures that enforce safety restrictions, and regulatory frameworks that evolve alongside AI-driven systems [5]. Beyond the technical and regulatory inspections, long-term exposure to humanoid may slowly reshape human expectations and interaction norms. Long-term studies suggest that users can develop an increased amount of comfort, emotional responsiveness, and social connection over time [63]. These shifts emphasize the need to understand long-term humanoid relationships, as evolving expectations play a key role in determining how they are eventually accepted in society [63].

5. Limitations

This review has several limitations that should be considered when interpreting its findings. First, as a narrative review, the study does not follow a fully systematic methodology, and as such should not be considered an exhaustive review. This may introduce selection bias in the identification and interpretation of relevant literature. However, efforts were made to include a broad range of sources, the selection may favor more accessible or frequently cited studies. Second, this review integrates evidence from diverse domains, including robotics engineering, clinical research, and industry reports. While this interdisciplinary approach provides a comprehensive perspective, it also presents challenges in balancing differences in methodological rigor, evaluation standards, and reporting styles across fields. Finally, the rapidly evolving nature of humanoid robotics means that some technological developments may not be fully captured at the time of writing, which may limit the long-term generalizability of the conclusions.

6. Conclusions

As humanoids move from experimental prototypes toward practical tools within human environments, a central question arises: what role will they ultimately play in society? Current evidence indicates that their most realistic future is not replacing humans but working harmoniously alongside them. Their advanced sensing systems, human-like form and growing autonomy position them to help with tasks that require physical interaction, collaboration, and adaptability, especially in settings such as healthcare and service work. Nonetheless, ongoing challenges in safety, reliability, trust and ethical governance make it clear that widespread integration will require slow, carefully managed deployment rather than a rapid transformation.

Therefore, when considering the future of humanoids, a balanced perspective is essential. Social acceptance, regulatory readiness and realistic public expectations will shape their long-term role just as strongly as technological breakthroughs that continue to expand their capabilities. A versatile thinking that combines robotics engineering with insights from medicine, ethics, psychology, and social sciences is key when addressing these factors. Only through this integrated approach can humanoids be developed and deployed in ways that enhance human well-being, support existing systems and integrate into complex environments they are designed to serve.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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