Robots in Society: Design, Functionality, and Ethical Challenges in Human-Robot Interaction

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Abstract

This article provides a comprehensive and comparative overview of the main types of robots, including social, educational, entertainment, industrial, collaborative, mobile, service, and humanoid robots, focusing on their technical, functional, and social characteristics. A key objective is to explore how anthropomorphic design, through human-like appearance, voice, and behavior, affects robot classification and shapes human-robot interaction in different domains, including healthcare, education, retail, and entertainment. The study utilizes a structured literature review methodology that integrates recent peer-reviewed research in engineering, human-computer interaction, and the behavioral sciences. Through a comparative analysis, the paper identifies overarching topics such as the merging of technology capabilities, the increasing fluidity of robot classifications, and the ethical implications of emotional engagement with robots. Factors related to user trust, perceived agency, and consumer acceptance such as emotional intelligence, contextual adaptability, design aesthetics, and interaction intensity are examined. The results show that the increasing anthropomorphism of robots can significantly enhance user engagement, emotional attachment, and acceptance. However, it also raises important ethical challenges. These include the risks of emotional manipulation, stereotype reinforcement, and psychological dependence. The paper highlights that successful robot integration depends not only on technical efficiency, but also on ethical considerations, context-aware design, and the alignment of robot behavior with human social expectations. This paper provides original value by connecting technical classifications with socio-psychological dimensions of human-robot interaction, offering a conceptual framework for understanding how design elements and application context interact to influence societal acceptance.

Keywords

Social robots, educational robots, entertainment robots, industrial robots, collaborative robots, service robots, humanoid robots.

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Introduction

Robots have transformed over the past few years from being specialized industrial tools to adaptable agents capable of executing complex tasks and engaging in social interactions. This transformation is primarily driven by advancements in artificial intelligence, sensor integration, and human-machine interface technology (Lee, 2021; Rubio et al., 2019). Currently, robots are progressively integrated into various sectors including education, healthcare, retail, logistics, and personal assistance. These include industrial manipulators, mobile drones, social robots designed for emotional interaction, and humanoid robots that replicate human gestures and behaviors (Pei and Nie, 2018; Zhang et al., 2024).

Artificial intelligence, sensor integration, and machine learning are leading robots forward at a remarkable pace. This is transforming the ways in which robots engage with people and function across different sectors, such as industry, healthcare, education, entertainment, and retail. While researchers are increasingly categorising robots according to their morphology, functionality, autonomy, and social role (Lee, 2021), technological convergence has obscured these traditional boundaries, resulting in the emergence of multifunctional, socially interactive robotic agents (Rubio et al., 2019). For instance, social robots have transitioned from being task-oriented assistants to companions that can engage in emotional interactions, employing anthropomorphic traits to enhance user trust and involvement (Gao et al., 2024; Pelau et al., 2025).

Research is currently emphasizing the possibilities and ethical challenges linked to the integration of robots into daily life. While anthropomorphic design strategies can improve human-robot interaction, they may also reinforce stereotypes and heighten perceptions of threat if not appropriately contextualized (Zhang et al., 2024; Pelau et al., 2024). Moreover, as emotional ties between humans and robots grow, especially in virtual and hybrid settings it prompts important questions into the authenticity of robot companionship and its psychological effects (Zou et al., 2023).

This paper addresses the research problem of how the design, functionality, and social integration of robots are evolving in different domains, and how these changes are reshaping the interactions between humans and robots. The approach involves a comprehensive literature review of recent studies on social robots, humanoid robots, educational robots, entertainment robots, industrial robots, service robots and mobile robots. By integrating the latest findings, the review identifies the key trends, challenges, and ethical considerations that will shape the future of robots. The structure of the paper begins by exploring robot classifications and anthropomorphism, continues by analysing functional applications across sectors, and concludes by outlining future research directions and the need for responsible, human-empowered innovation.

Methodology

The objective of our research is to explore the main types of robots and their applicability in different domains, with a particular focus on how their technical features and social functions influence user perception and interaction. This research also intends to assess the role of anthropomorphic design in shaping the classification, emotional engagement and social acceptance of robots. To achieve this, we performed a structured literature review based on academic sources indexed in the Web of Science database.

The type of robot discussed in each study served as the primary selection criterion. Peer-reviewed publications that addressed at least one of the following topics were included: humanoid robots, industrial robots, collaborative robots, social robots, educational robots, entertainment robots, mobile robots, and service robots. Keyword combinations associated with each type of robot were used in the search process, along with phrases like "anthropomorphism," "user perception," and "ethical challenges." Research was eliminated if it failed to specifically address one of the targeted robot categories or its technical, functional, and social aspects that are related to the context of human-robot interaction.

The selected studies were analysed using qualitative content analysis to identify key themes related to robot morphology, autonomy, interaction style and emotional intelligence. Comparative insights were provided across multiple domains, including healthcare, education, retail, industrial automation, and entertainment, to understand how robots are designed and adapted to domain-specific needs and their applicability. This methodological approach provided the basis for the theoretical insights and practical implications discussed in the remainder of the article and allowed for a synthesis of technical and socio-psychological perspectives.

Results

The results of this paper show that robots are increasingly being integrated into a wide range of domains, including healthcare, education, entertainment, industry, logistics and retail, each with different functional needs and social roles. Robots are evolving into socially interactive, emotionally responsive and multifunctional systems that are no longer limited to isolated task-based operations. The applicability of each type of robot is closely linked to its morphology, level of autonomy and ability to interpret and respond to human behaviour.

In addition, while anthropomorphic features increase trust and acceptance, they also raise ethical concerns, such as emotional deception and the strengthening of stereotypes. In industrial settings, precision and collaboration are dominant; in education and health care, emotional intelligence and user adaptability are key. The results confirm the growing trend of robot classification integration, the increasing importance of context-aware design, and the need for multidisciplinary approaches to ensure socially responsible and human-robot integration.

Robots in different domains and technological integration

Robots are now essential in a wide range of fields, including personal services, healthcare, education, entertainment, and industrial production. Robots are increasingly categorised in academic literature according to their morphology, functionality, degree of autonomy, and social role (Lee, 2021). As technological convergence accelerates up, particularly with the emergence of artificial intelligence (AI), robots are developing into sophisticated, multifunctional agents that can act independently in a variety of settings and interact with people in a natural way (Rubio et al., 2019).

Social robots, anthropomorphism, and human-robot interaction

Social robots are a developing class of artificial agents intended to carry out emotional and communicative tasks in both home and business settings. The research of Gao et al. (2024) shows that social home robots (SHRs) like Jibo, Kuri, and Buddy are designed to mimic emotional support and domestic companionship. These robots use anthropomorphic designs to boost perceived intelligence and user engagement. However, a lot of social home robots fail commercially despite high expectations because of unclear value statements, privacy concerns, and low consumer trust. Self-construal, perceived support, and usage intention are all mediated by trust, indicating that social cognition theories are crucial for simulating acceptance.

The concept of anthropomorphism is applicable to a variety of robot domains. Anthropomorphic features, like gendered voices, facial expressions, and socially stereotypical behaviours, can increase trust and engagement when they are in line with user expectations, according to Zhang et al. (2024) systematic review of 118 studies. However, in delicate service contexts like healthcare, overuse of anthropomorphism can also increase feelings of threat, strengthen stereotypes, and decrease acceptance. Song and Kim (2022) further demonstrate that in humanoid retail service robots (RSRs), human-robot interaction (HRI) depends heavily on the robot's perceived usefulness, social capability, and appearance. The CASA theory (Computers Are Social Actors) explains why humans engage socially with robots that offer enough human-like cues. However, robot anxiety, triggered by feelings of eeriness or discomfort, can inhibit consumer acceptance, underlining the delicate balance designers must achieve when creating service robots.

Recent research has shown that emotional drivers such as empathy, attachment and warmth, as well as functional efficiency, shape consumer interaction with AI. Pop et al. (2023) highlight that interaction quality, in combination with anthropomorphic features and emotional expressiveness, significantly increases user trust and ongoing acceptance. Further to the study, customers may develop social relationships with AI systems as a result of frequent, tailored interactions, viewing them as friends rather than just tools. These results support the expanding use of social and emotionally responsive service robots in industries like retail, education, and healthcare, where adoption depends on human-like engagement and trust.

Humanoid, educational, and entertainment robots

Humanoid robots, which are machines made to mimic human form and human biomechanics like walking, gesturing, and sitting, are closely related to social robots. A major advancement in robotics research, humanoid robots seek to mimic human form as well as human-like movement, manipulation, and cognitive capacities (Rubio et al., 2019). As a prime example, Yu et al. (2014) highlight the BHR-5 humanoid robot's aluminium build, hard plastic exterior, and sophisticated sensory systems, which include cameras, accelerometers, force/torque sensors, gyroscopes, and accelerometers. The robot's open architecture allows for modular development for future research, and its ability to walk at 2.0 km/h and execute complex tasks like playing table tennis shows sophisticated stability control using Zero-Moment Point (ZMP) strategies.

In education, robots are being used more and more as teaching assistants and learning partners. Intelligent assistant robots, virtual simulation platforms, multifunctional suite robots are all types of educational robots (Pei and Nie, 2018). It has been demonstrated that these robots enhance learning outcomes, teamwork, and student engagement, especially in special education and language learning. Ouyang and Xu (2024) emphasize the strong positive effects of programming robots, such as Lego Mindstorms and VEX Robotics, on student performance and computational thinking development. Although social robots have a somewhat smaller direct effect on learning outcomes, they contribute significantly to motivation and engagement through human-like interaction capabilities.

Entertainment robots are another category that is gaining prominence. Fujita and Kitano (1998) introduced MUTANT, a pet-like, four-legged robot developed by Sony that incorporated emotional modules, stereo microphones, and touch sensors to generate life-like behaviors. Designed for robot entertainment, MUTANT demonstrated how emotionally engaging machines could normalize the presence of robots in domestic environments and advance research on embodied AI. Wang et al. (2025) further classify entertainment robots into musical performance robots, dance robots, violin-playing robots, singing robots, and marimba-playing robots. Systems like Shimon exemplify the use of non-verbal cues, such as head movements, to enhance synchronization with human musicians, while violin-playing robots utilize reinforcement learning algorithms to master bowing techniques, illustrating the fusion of mechanical dexterity and AI-driven expressiveness.

Industrial, collaborative, and mobile robots

Meanwhile, the industrial sector continues to be dominated by robots designed for precision, speed, and durability in structured environments. Singh and Banga (2022) emphasize the critical role of inverse kinematics in the design of industrial robots used in welding, assembly and material handling. Traditional robots in industrial settings often operate in isolated workspaces. However, there has been a shift towards collaborative robots, or cobots, that can work safely alongside humans without protective barriers. Simões et al. (2020) argue that factors such as workforce readiness, process integration, competition, and regulatory pressures influence the adoption of cobots. Dzedzickis et al. (2021) further highlight examples such as the Universal Robots UR5 and Franka Emika Panda, cobots that are easily programmable and adaptable for human-centered automation, aligning with Industry 4.0 trends.

Robots are also making significant contributions to routine industrial operations and hazardous environments through telerobotics. Sheridan (2016) differentiates between semi-autonomous telerobots used in factories and warehouses, and fully human-controlled teleoperators deployed in extreme environments like space missions or underwater exploration. These robots extend human operational capabilities while addressing risks associated with direct human involvement. Although communication latency remains a challenge, telerobots and teleoperators underscore the critical synergy between human cognition and robotic precision.

Autonomous systems extend the reach of robotics into transportation and logistics. Autonomous passenger and cargo vehicles integrate navigation algorithms, environmental sensing, and adaptive control to provide partial or full autonomy, ensuring safety and efficiency in increasingly complex environments. In agriculture, autonomous robots automate essential tasks such as sowing, plant identification, and harvesting, significantly increasing productivity and sustainability (Dzedzickis et al., 2021).

Mobile robots represent another critical development, defined by their ability to navigate autonomously in dynamic and unstructured environments. Rubio et al. (2019) and Zhang et al. (2019) discuss how mobile robots, including wheeled, legged, aerial, and aquatic platforms, use sophisticated motion planning strategies that integrate global, sensor-level, and action-level trajectories. Their operation requires robust navigation algorithms, perception of the environment, and adaptation in real time. The authors highlight how new developments in AI and robotics, such as simultaneous localization and mapping (SLAM) and cooperative multi-robot systems, have significantly increased operational capabilities across industries.

Embodiment and service robots

The perception of robot agency and embodiment becomes especially complex within virtual and hybrid environments. Zou et al. (2023) explore how social robots, particularly through platforms like Character AI, provide emotional companionship by simulating social presence without true embodiment. The emergence of such disembodied AI agents highlights the shift towards virtual identity formation in the metaverse. While chatbots and AI companions offer emotional connection, the relationship remains asymmetrical and ethically controversial: humans dominate these interactions, while robots passively imitate companionship without genuine reciprocity. Emotional connections formed with social robots are often described as emotional deception, raising concerns that overreliance on AI companions may weaken users' ability to form authentic human relationships (Zou et al., 2023).

Service robots are rapidly adopted across hospitals, hotels, homes, and retail environments. Lee (2021) classifies service robots into professional non-social, professional social, domestic non-social, and domestic social categories. Each type demands different levels of interaction, adaptability, and technological complexity. Healthcare robots, for example, must navigate crowded hospital wards, interpret social cues, and comply with stringent hygiene protocols, necessitating seamless AI and ergonomic integration. In retail, humanoid service robots such as Pepper and NAO (Song and Kim, 2022) provide interactive shopping experiences, showcasing how embodiment, appearance, and social responsiveness drive consumer acceptance or rejection.

A growing body of literature questions how much control AI robots have. To assess how anthropomorphic design influences perceptions of robot agency, Pelau et al. (2024) adopted a scenario-based approach. The study finds that qualities such as moral responsibility, opinion, and identity are more likely to be attributed to robots with a human-like appearance. In particular, men were found to be more likely than women to attribute agency to these robots. This reflects broader societal perceptions about the embodiment of AI and the blurred line between machines as tools and machines as intentional agents.

Throughout these developments, several thematic insights emerge. Anthropomorphism, while useful in promoting user engagement, introduces ethical and psychological dilemmas, particularly when deployed in emotional or moral contexts (Zhang et al., 2024; Pelau et al., 2024). The importance of user trust and age-related acceptance in robot adoption is also emphasized by recent findings. Ciofu et al. (2024) show that younger users have a higher tolerance for robot errors and greater trust in integrating AI systems into customer interactions, suggesting that generational familiarity with the technology strongly influences acceptance. Technological advances such as machine learning, affective computing, and real-time sensor integration are becoming universal across all robot types, but are expressed differently depending on context, whether enhancing precision in factories or fostering empathy in domestic settings. The emotional companionship offered by robots, particularly disembodied agents, raises ethical concerns about authenticity, manipulation, and long-term social adaptation (Zou et al., 2023).

Robots designed to simulate emotional and social behaviors, such as AIBO, NAO, LOVOT, and RoBoHoN, are gaining increased attention. (Joshi et al. 2024) discuss how accessorization, through aesthetic modifications or interactive attachments, deepens emotional bonding between users and robots, enhancing acceptance and user experience. Customization strategies tap into the psychological processes of attachment and personalization, which are critical for widespread adoption.

Conclusions

This paper reviews the main types of robots in different domains, highlighting how they differ in design, function, and interaction with humans. A key finding is the growing influence of anthropomorphism, which can increase user confidence, but is also a source of ethical concern. The study shows that the classification of robots is becoming more fluid as technologies merge.

Research findings illustrate that as technologies evolve and merge, the classification of robots by type, social, educational, industrial, humanoid, or mobile-is becoming increasingly fluid. However, the different challenges and opportunities associated with each of these categories underline the need for context-specific design, ethical foresight, and interdisciplinary research. As robots become more integrated into everyday life and public services, a deeper understanding of their design, perception, and function will be crucial to guide their responsible development and societal acceptance.

Humanoid and entertainment robots highlight significant efforts to mimic and complement human behaviour, while telerobots and autonomous systems demonstrate the potential to extend human capabilities into hazardous and inaccessible environments. In healthcare and education, robots are improving precision, accessibility, and engagement. They are fundamentally changing traditional practices. Social robots are creating new forms of companionship through personalisation and emotional expressiveness. They are also strengthening human-robot interactions. Mobile robots, equipped with hybrid and real-time planning strategies, ensure safe and natural integration into dynamic shared environments.

The study also emphasises the need for context-aware and ethically responsible design of robots, especially in socially sensitive areas such as health care and education. It also calls for more in-depth research into the long-term interactions between humans and robots and for the development of inclusive and culturally sensitive design principles. Future research should explore hybrid, adaptive systems that meet complex human needs in dynamic environments, as robots continue to integrate with AI and other emerging technologies.

Critical attention must be paid to fostering interdisciplinary collaboration, promoting ethically responsible innovation, and prioritising user-centred design as robots continue to advance. The future of robots is not only about improving task efficiency, but also about fostering meaningful, empathetic human-machine interactions in diverse social, industrial, and personal contexts.

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