Proceedings of CONF-MLA 2026 Symposium: Intelligent Systems and Automation: AI Models, IoT, and Robotic Algorithms
DOI: 10.54254/2755-2721/2026.LD39492

From Replacement to Augmentation: A Human-Centered Framework for Consumer Robots

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Abstract. Artificial intelligence and related hardware and software technologies have accelerated the development of consumer robots, creating new opportunities for robots to support people in everyday life. However, advanced technology is only the foundation for achieving this goal. A complete design concept for robots aimed at ordinary consumers is also needed. This paper examines the importance of positioning consumer robots as tools for human augmentation, the reason why consumer robot interaction design should mainly use intuitive operation, and the safety issues that influence user trust and acceptance. The analysis argues that consumer robots should prioritize human augmentation rather than complete robot autonomy. This approach protects consumer control while giving users stronger capabilities. In addition, robot products can only be psychologically accepted when consumers trust them. To achieve this positioning, intuitive interaction can reduce the barriers for ordinary consumers and allow more natural interaction. Products should also provide data privacy protection, control-right protection, and safety that can be perceived by users. The significance of this paper is that it provides a consumer-centered design framework for robots aimed at ordinary consumers.

Keywords: Consumer robots, Human augmentation, Shared control, Intuitive interaction, Multidimensional safety

1. Introduction

At present, robots have been widely used in industry and have significantly improved productivity and industrial production efficiency. In the future, the robot industry for ordinary consumers will also continue to develop. Consumers increasingly expect robots to provide practical assistance and improve the convenience of daily life.

However, much existing research focuses on specific technical methods that enable robots to complete tasks autonomously, with relatively limited attention to the needs and psychology of consumers when robots operate in everyday environments. Consumer robots also face requirements beyond task performance, including safety, data privacy, user control, and trust. Therefore, relatively limited research has constructed a systematic design framework for robots aimed at ordinary consumers from a consumer-centered perspective.

To make robots accepted by ordinary consumers and make them willing to deploy robots in homes and work environments, a set of product positioning, interaction design, and safety

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considerations for ordinary consumers is needed. Therefore, it is not sufficient to define product value only by autonomy, task completion rate, or degree of human-like appearance. This paper studies the importance of positioning consumer robots as human augmentation, the reason why consumer robot interaction design should focus on intuitive operation, and the safety construction of consumer robots. This paper uses a literature research method. It summarizes and compares research related to human augmentation, human-robot interaction, shared control, robot safety, and privacy protection. By analyzing user psychology, characteristics of different interaction methods, trust, and safety issues in different studies, this paper extracts and constructs a design framework for robots aimed at ordinary consumers. This study is expected to provide a consumer-centered product framework for the growing consumer robot market.

2. Product positioning: from human replacement to human augmentation

2.1. The concept of human augmentation and consumer robot positioning

Human augmentation has been applied in various medical and assistive technologies. For example, prosthetic technology helps people with disabilities regain mobility. The da Vinci robot from Intuitive Surgical allows clinical surgery to overcome some spatial limitations. Nevertheless, it is still necessary to give a clear definition of human augmentation.

De Boeck and Vaes analyzed a large amount of research literature and gave a clear definition of human augmentation. They state that Human augmentation can be achieved by developing device-based technologies that replicate, supplement or exceed human abilities in physical, sensory, cognitive or social scenario [1]. This establishes a new paradigm for evaluating consumer robots, unlike controversial opinions that the more commensurate a robot's capabilities are to those of humans, the more powerful it becomes.

For consumer robots, this concept means that robots should be designed to restore, supplement, or extend users' capabilities rather than simply perform tasks in place of them. Positioning consumer robots as human augmentation therefore gives products a clearer purpose and allows them to integrate more naturally into consumers' lives. It enables robots to extend user capabilities while preserving meaningful user control.

2.2. Technical and application limitations of complete human replacement

Another reason for positioning consumer robots as human augmentation instead of complete human replacement is that complete human replacement faces technical and application limitations.

From a technical perspective, to fully replace humans, robots must act correctly and continuously in environments full of unusual situations. However, machine learning training data are limited and cannot fully cover all unusual events and sudden risks. Especially in unstructured environments such as everyday settings, weather, lighting, sensor failures, and unusual object interactions can cause a shift between operational data and training data. This reduces the reliability of model perception and decision-making [2].

From an application perspective, the goal of complete human replacement may also be problematic as a product-design objective. Consumer robot tasks are ultimately defined by human needs and preferences, and automating a specific task does not necessarily require transferring the entire decision-making process to the robot. Sarah Dégallier-Rochat and others stated in their paper on human augmentation that academia and industry should give up the obsession with completely replacing humans with robots and instead focus on the quality of human-machine interaction [3].

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Overall, the positioning of consumer robots as complete human replacement faces challenges in terms of both technical limitations and application rationality.

2.3. User preferences and human control rights

Positioning consumer robots as human augmentation can also meet user preferences and users' sense of control. Studies show that people tend to prefer special-purpose robots over general-purpose robots for tasks such as medication management, stair assistance, and vacuuming. In these tasks, people also have clear safety and privacy concerns about general-purpose humanoid robots. Although technology companies use home care by general-purpose humanoid robots as an important selling point, experiments show that most participants do not currently want humanoid robots to enter their homes [4]. In addition, many people are concerned about the practicality and spatial suitability of general-purpose humanoid robots.

These findings suggest that clear and bounded robot functions may make the purpose of consumer robots easier to understand and may increase users' sense of safety and control. For complex and high-risk tasks, users do not want robots to complete the tasks entirely by themselves.

2.4. Principles of human-augmentation-oriented product positioning

In summary, human-augmentation-oriented product positioning should follow two principles. First, consumer robots should have clear functional purposes and should restore, supplement, or extend users' capabilities rather than pursue human replacement as the primary objective. At the same time, they should protect user control rights, safety, and privacy from both psychological and practical perspectives.

3. Intuitive interaction as a key mechanism for human augmentation

3.1. Why consumer robots need intuitive interaction

Consumer robots are intended for ordinary users rather than robotics specialists.Therefore, human-robot interaction should be easy to understand, operate, and control. Complex or highly technical interaction methods can increase users' learning costs and create barriers to adoption. For example, users may need to use a two-dimensional interface to control a three-dimensional world [5]. This means that even if people can receive help from robots, their willingness to use robots may decrease. This directly reduces the popularity of the product. Therefore, designers should focus on how to provide consumer robots with natural human-robot interaction methods with low learning costs.

One important direction is to make interaction methods adapt to human behavioral habits. This is intuitive interaction. Intuitive interaction matches four characteristics of ordinary consumers in everyday use scenarios. First, operators often lack a background in robotics or engineering and have low tolerance for complicated user experiences. Second, consumer robot functions and hardware may be limited, so good interaction design is needed to compensate for these limitations. Third, the environment is relatively structured, and environments such as supermarkets and homes have some predictability. Finally, error tolerance is relatively high, and minor collisions or delays may be acceptable [6].

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3.2. Ways to achieve intuitive interaction

To achieve intuitive interaction, users should interact with robots primarily at the level of goals and intentions, while robots handle the technical details required for execution. Low-level technical commands can therefore be converted into high-level expressions such as task goals, object selection, and behavioral constraints. Users express their intentions and leave the execution of low-level details to the robot system. Unnecessary technical details should also be hidden so that users can focus on controlling robots at the task level rather than the hardware level [6].

For command input, users should be allowed to use multimodal methods such as voice, touch screens, gestures, wearable devices, and biological signals. For example, Electromyography (EMG) signals can reflect a user's movement intention before an actual movement occurs. They can be used for prosthetics, exoskeletons, rehabilitation, and robot control. However, EMG signals are easily affected by electrode shifts, muscle fatigue, limb posture, and individual differences [7].

Shared control is an important mechanism for achieving intuitive interaction. Users are responsible for goal setting and key judgments, while robots handle obstacle avoidance, joint limits, and low-level motion control. Shared control can also use visual, auditory, or tactile feedback to explain robot intentions and risks to users. This allows users to confirm, modify, pause, or take over tasks. In this way, shared control reduces operational burden while preserving user control rights [8].

4. Multidimensional safety: a foundation for consumer robot adoption

4.1. Data privacy and cybersecurity

Data privacy and cybersecurity are important conditions for the wider adoption of consumer robots. Consumer robots may perceive, record, and process information from users' private environments. In addition, the cybersecurity of consumer robots should be taken seriously to reduce the possibility of malicious manipulation and attacks. According to a survey, 74.4% of respondents listed "eavesdropping/privacy leakage/hacking" as their main concerns. They also strongly disliked business models that could lead to the secondary sale of private data [9].

Existing cybersecurity attacks include physical attacks on sensors, such as GPS spoofing and gyroscope tampering as well as digital attacks targeting actuators, control systems, and AI models [10]. To strengthen data privacy and cybersecurity, product design can include physical switches with one-button disconnection functions. Users should also be provided with mechanisms to view, export, and delete their personal data, while the purpose of data use should also be clearly explained [11].

4.2. Perceived safety, trust, and user acceptance

Perceived safety is another important condition for consumer acceptance of robots. Governance frameworks and ethical design guidelines, such as the European Union Artificial Intelligence Act and IEEE Ethically Aligned Design, emphasize the protection of human autonomy and sense of agency as core ethical principles [12]. If the behavior of a consumer robot makes users feel out of control or forced to obey, it may cause psychological discomfort. The key factors for improving perceived safety in autonomous systems include movement predictability, user control, suitable speed and distance, social cues, and communication of action intentions [13]. Therefore, consumer robots should not only provide actual physical and technical safety but also make their behavior

DOI: 10.54254/2755-2721/2026.LD39492

understandable, predictable, and controllable to users [14]. In this way, users can psychologically accept and confidently use the product.

5. Integrated design framework for consumer robots

Based on the previous analysis, this paper proposes an integrated design framework for consumer robots aimed at ordinary consumers. The framework positions human augmentation as the product, intuitive interaction as the primary interaction mechanism, and multidimensional safety as the foundation for trustworthy and long-term use. These three elements are not independent design requirements. Together, they determine whether consumer robots can be accepted and used by users over the long term.

At the human augmentation level, product design should clearly address users' actual needs. Robots should prioritize assisting with repetitive, time-consuming, physically demanding, or difficult tasks that users cannot complete independently. Robots should not aim to replace users in all activities. The product should clearly define which tasks are decided by users, which tasks can be assisted by robots, and which high-risk tasks must retain user confirmation and takeover.

At the intuitive interaction level, the system should allow users to express their goals and intentions through everyday language and actions. The design focus should not be to provide as many control functions as possible. Instead, it should allow users to clearly express goals, understand the robot's state, and modify, pause, or cancel tasks when necessary. Users of different ages, abilities, and levels of technical experience should be able to learn consumer robot operation and interaction skills with low learning costs.

At the multidimensional safety level, product design should treat safety as a foundation throughout the stages of positioning, interaction, and deployment, rather than as a function added after the product is completed. Users have the right to know what types of data are recorded by the robot, how the data are processed, and what the data are used for. They should also have the right to export and delete all data recorded by the robot. In addition, robots should include a forced shutdown function to deal with highly unusual situations that cannot be covered during training. While ensuring actual safety, designers should also fully consider users' psychological and perceived safety. This can make users more willing to accept and use the product over the long term.

Therefore, this framework emphasizes that consumer robots are not necessarily more valuable simply because they are more autonomous, more general-purpose, or more human-like. Their core value lies in providing appropriate and reliable capability support while users retain control rights, understand system behavior, and receive safety and privacy protection.

6. Conclusion

This paper argues that consumer robots should not blindly pursue autonomy, task completion rate, or the level of human-like appearance. Instead, they should be positioned around human augmentation. Robots for ordinary consumers should have clear task purposes. They should naturally restore, supplement, or extend users' abilities to improve their quality of life. At the same time, they should protect user control rights, safety, and privacy from both psychological and practical perspectives. This approach also better matches user preferences and needs.

To achieve this positioning and to consider the characteristics of everyday environments and lower the barriers to use, consumer robots should adopt intuitive interaction design. They should allow users to express intentions through high-level and multimodal methods. Through shared

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control, robots should handle low-level control details, while users retain the rights to confirm, modify, pause, and take over tasks.

In addition, consumer robots should protect data privacy, cybersecurity, and psychological safety at the same time. Only when robots are actually safe and make users feel safe can consumers trust, accept, and use the product over the long term. The consumer-centered design framework proposed in this paper can provide a reference for consumer robot product development and evaluation, although it glosses over technical details, which are anticipated to be delved into the future research.

As the framework is basically constructed on recent robotic techniques and previous research on customers' opinions and reflections on consumer robots, the future research is expected to contrive products according to the framework, deploy them to the market, and iteratively gather and probe user feedback. Also, barring having awareness of consumers' predilections, tenacious technique development and empirical refinement are imperative to make good on the framework's promise of human argumentation, natural interaction design, reliable privacy, and tangible security.

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