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EMBODIED INTELLIGENCE IN ASSISTIVE TECHNOLOGIES FOR THE VISUALLY IMPAIRED: ENHANCING INDEPENDENCE AND SOCIAL INCLUSION

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ABSTRACT
This paper investigates the application of Embodied Intelligence (EI) in assistive technologies for the Blind and Low Vision (BLV) community. The research identifies the specific needs and challenges faced by visually impaired individuals and introduces an EI framework that combines perception, decision-making, and action execution to improve their quality of life and social participation. The study emphasizes the potential of multimodal perception and intelligent decision-making in delivering personalized support and enhancing user experience. Moreover, it addresses the importance of social acceptance and ethical considerations for the successful deployment of these technologies. The findings underscore the need for ongoing research and development to ensure that EI can be practically and sustainably applied to increase the independence and confidence of the BLV population.

Keywords: Embodied Intelligence, Assistive Technologies, Visually Impaired, Human-Machine Interaction

1 INTRODUCTION

People who are blind or have low vision (BLV) face significant challenges in their daily lives, impacting mobility, access to information, and social interaction. Navigating unfamiliar environments, interpreting written and visual information, and engaging in meaningful social activities are daily struggles for this community. According to the World Health Organization, visual impairments are classified into four categories: complete blindness, severe low vision, moderate low vision, and normal vision, providing a framework for understanding their needs and designing tailored solutions [1][2]. These classifications are vital for ensuring assistive technologies meet diverse user requirements and accommodate varying degrees of impairment [3].

Figure 1. Different Types of Visually Impaired Populations

Figure 1 illustrates the spectrum of visual impairments, highlighting the distinct challenges faced by individuals in each category. For instance, those with complete blindness often depend on auditory or tactile feedback, while individuals with moderate low vision may benefit from tools that amplify remaining visual capacities [4]. Such distinctions emphasize the need for adaptive solutions that can address the wide-ranging demands of the BLV community [5][6][7].

In recent years, significant advancements have been made in assistive technologies, such as smart glasses, voice-controlled digital assistants, and intelligent canes, which have improved mobility and access to information [8][9]. However, despite these innovations, existing solutions frequently fall short in addressing the comprehensive needs of users, including personalized interactions, seamless integration into daily life, and adaptability to dynamic environments [10][11]. The growing prevalence of visual impairments, driven by aging populations and chronic conditions like diabetes, further amplifies the urgency for effective and scalable solutions [12]. Moreover, the significant investment in assistive technologies reflects their critical role in enhancing the quality of life for visually impaired individuals [13][14][15].

Embodied Intelligence (EI) has emerged as a promising paradigm for overcoming these limitations. EI integrates perception, cognition, and physical interaction, creating systems capable of dynamic adaptation and contextual understanding [16]. By leveraging advanced sensors, artificial intelligence (AI) algorithms, and real-time feedback mechanisms, EI-based solutions can address diverse and complex user needs [17][18]. Unlike conventional technologies, which often rely on singular modalities, EI employs multimodal inputs, such as auditory, tactile, and visual data, to offer a holistic and intuitive user experience [19][20][21].

This paper proposes a novel framework for applying EI in assistive technologies specifically designed for the BLV community. Key components of this framework include multimodal perception for processing environmental data, intelligent decision-making to prioritize actions, and real-time execution for adaptive interaction [22][23][24]. For example, multimodal systems can combine spatial audio cues with tactile feedback to guide users more effectively through unfamiliar environments [25]. Furthermore, intelligent algorithms ensure that assistive devices can respond appropriately to changes in context, such as detecting obstacles or navigating complex indoor spaces [26][27].

Addressing ethical and social considerations is equally crucial for the successful deployment of these technologies. Issues such as user privacy, the affordability of devices, and their societal acceptance must be taken into account to ensure widespread adoption [28][29]. Figure 1 reinforces the diversity of challenges and underscores the importance of targeted solutions that cater to the unique needs of visually impaired individuals [30].

Through a detailed exploration of embodied intelligence and its practical applications, this study aims to bridge the gaps in existing assistive technologies and contribute to a more inclusive society [31][32]. The proposed framework aligns the technical capabilities of EI systems with the specific challenges faced by the BLV community, ultimately enhancing their independence, mobility, and social engagement [33][34][35].

This paper is structured as follows: Section 2 reviews the literature on assistive technologies, identifying key limitations. Section 3 discusses the theoretical foundations of embodied intelligence. Section 4 introduces the EI-based framework, while Sections 5 and 6 evaluate its effectiveness through case studies and experimental results. Finally, Section 7 highlights future research directions and concludes with the broader implications of this work for the visually impaired population. By addressing these pressing challenges, this research aspires to empower individuals with visual impairments and promote innovative solutions that enhance their daily lives.

2 THE CURRENT SITUATION AND NEEDS OF THE VISUALLY IMPAIRED POPULATION

2.1 Blindness and Low Vision (BLV): Definition and Classification

Blindness and Low Vision (BLV) denote significantly reduced visual capabilities, encompassing both complete blindness and varying degrees of low vision. Total blindness is characterized by a complete absence of vision, while low vision refers to conditions where visual acuity falls below certain thresholds, such as 0.3 or 20/70. According to the World Health Organization (WHO), visual impairments are further categorized into complete blindness, severe low vision, mild low vision, and normal vision. These classifications provide insights into the diverse needs and challenges that individuals with various levels of visual impairment face, serving as a basis for developing assistive technologies.

2.2 Challenges Encountered by the BLV Population

People with visual impairments encounter numerous challenges in their daily activities, primarily in areas such as mobility, safety, information access, and social interaction. For example, without critical environmental information, navigating public spaces can be hazardous, increasing the risk of accidents. Additionally, these individuals face significant obstacles in accessing information and engaging in social interactions, which can negatively impact their quality of life and hinder their career opportunities and social involvement.

2.3 Analysis of the Need for Assistive Technologies

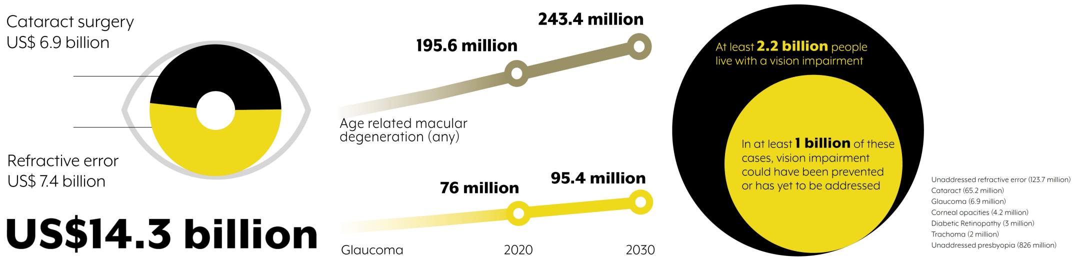

Figure 2. Need for Assistive Technologies. (left) Investment Required to Treat Existing Unaddressed Cases of Refractive Error and Cataracts Globally. (middle) Projected Number of People with Age-Related Macular Degeneration and Glaucoma from 2020 to 2030. (right) Proportion of Individuals with Visual Impairment and Those Whose Condition Could Have Been Prevented or Is Still Unaddressed.

With a vast number of individuals affected by unaddressed cases of refractive error and cataracts worldwide, the investment needed to address these issues is estimated at $14.3 billion, as shown in Figure 2(left). Additionally, Figure 2(middle)(right) depicts a consistent annual increase in the global population affected by visual impairments. While emerging technologies have shown promise in improving the lives of visually impaired individuals, current assistive devices still exhibit limitations, such as limited convenience, poor user experience, and insufficient personalization. Consequently, there is an urgent need for more intelligent, adaptive, and personalized assistive technologies to improve the quality of life, social inclusion, and self-confidence of the BLV community. Exploring the potential of embodied intelligence in this domain could help meet these unmet needs.

3 DEVELOPMENT AND CONCEPT OF EMBODIED INTELLIGENCE

3.1 Embodied Intelligence: Definition and Innovation

Embodied Intelligence (EI) is not merely an integration of perception, cognition, and physical actions; it represents a paradigm shift in how we conceive intelligent systems. Traditionally, intelligence has been viewed as an abstract cognitive process, detached from the physical world. EI challenges this view by asserting that true intelligence is inseparable from the body and its dynamic interaction with the environment. This framework introduces a novel approach where the physicality of the agent is central to its intelligence, enabling a more nuanced and context-aware decision-making process. By embedding the agent within a physical context, EI systems can adapt to changes in real-time, responding with actions that are not just reactive but also predictive, based on a deep understanding of the environment and the agent's goals. This synthesis of elements introduces new knowledge by bridging the gap between cognitive processes and physical actions, creating a more holistic and effective model for intelligent systems.

3.2 Theoretical Foundations of Embodied Intelligence

The theoretical foundation of EI combines insights from cognitive science and robotics, proposing that an agent's cognitive abilities are deeply intertwined with its body and environmental interactions. The "body-mind" model from cognitive science challenges traditional brain-centric views, highlighting the influence of bodily structure on cognitive processes. Through multimodal perception, EI systems can adapt dynamically to complex environments. Furthermore, by incorporating elements of robotics and artificial intelligence, EI enables robots to exhibit advanced adaptability, empowering them to make complex decisions in changing environments. This interdisciplinary research advances robotic intelligence, particularly in human-robot interactions, where EI systems offer more natural and intuitive experiences. In essence, EI supports the design of intelligent systems and paves the way for more effective human-machine interaction.

3.3 Domains of Application for Embodied Intelligence

Embodied Intelligence has a broad range of applications, including humanoid robots, autonomous vehicles, and assistive technologies. Within assistive technology, EI provides novel solutions for improving the lives of visually impaired individuals, enhancing their quality of life and promoting social inclusion. As research progresses, EI's application prospects are expected to expand, driving intelligent development across various fields. For example, OrCam glasses illustrate the application of artificial intelligence in assistive technology by enabling visually impaired individuals to read printed text, recognize supermarket items, identify currency, and even recognize faces, significantly enhancing convenience for these users (as depicted in Figure 3).

Figure 3. Application of OrCam Glasses for Visually Impaired Individuals

4 EMBODIED INTELLIGENCE APPLICATIONS IN ASSISTIVE TECHNOLOGIES

4.1 Current Assistive Technologies Overview

With rapid advancements, assistive technologies have introduced a variety of solutions designed to help visually impaired individuals overcome daily challenges. Currently available devices, such as smart glasses, voice assistants, and intelligent canes, assist with environmental perception, navigation, and information transfer. However, many existing technologies still face limitations regarding user experience and interaction, highlighting the need to explore embodied intelligence to develop more comprehensive assistive solutions.

4.2 Potential of Embodied Intelligence within Assistive Technologies

By integrating perception, decision-making, and physical action, embodied intelligence represents an innovative approach to advancing assistive technologies and improving the lives of visually impaired individuals.

4.2.1 User Experience and Interactivity

Embodied intelligence enhances assistive technologies' interactivity by offering two primary benefits. First, these systems respond in real-time to user needs and environmental changes, providing assistance through voice and tactile feedback to aid with mobility. Second, EI systems allow for natural interaction methods like voice commands and gesture control, simplifying operation and optimizing user experience. Research has shown that wearable low-vision devices, such as the OrCam MyEye 2.0, which translates visual information into audio feedback, can significantly enhance reading abilities for individuals with advanced hereditary retinal dystrophies and cone-rod dystrophies. Figure 4 illustrate this improvement, displaying the mean score enhancement on the Visual Functioning Subscale before and after using the OrCam device [36].

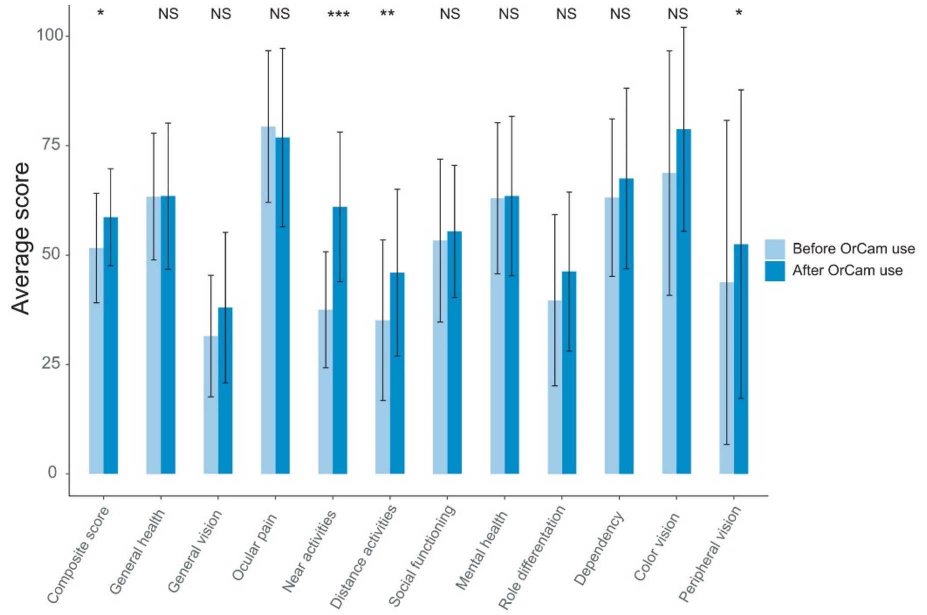

Figure 4. Average scores on the subscales of the National Eye Institute Visual Functioning pre- and post-rehabilitation with the OrCam [36].

4.2.2 Services Personalized and Adaptability

The adaptability of EI systems is essential for visually impaired users, enabling them to navigate dynamic environmental challenges effectively. By continuously collecting and analyzing environmental data, these systems can adjust strategies in real-time to maintain user safety and convenience. Additionally, EI provides personalized services by analyzing user data to deliver relevant information based on individual habits, thereby enhancing user engagement and independence. This personalized experience not only improves quality of life but also boosts users' social confidence.

5 FRAMEWORK CONSTRUCTION FOR THE THEORETICAL MODEL

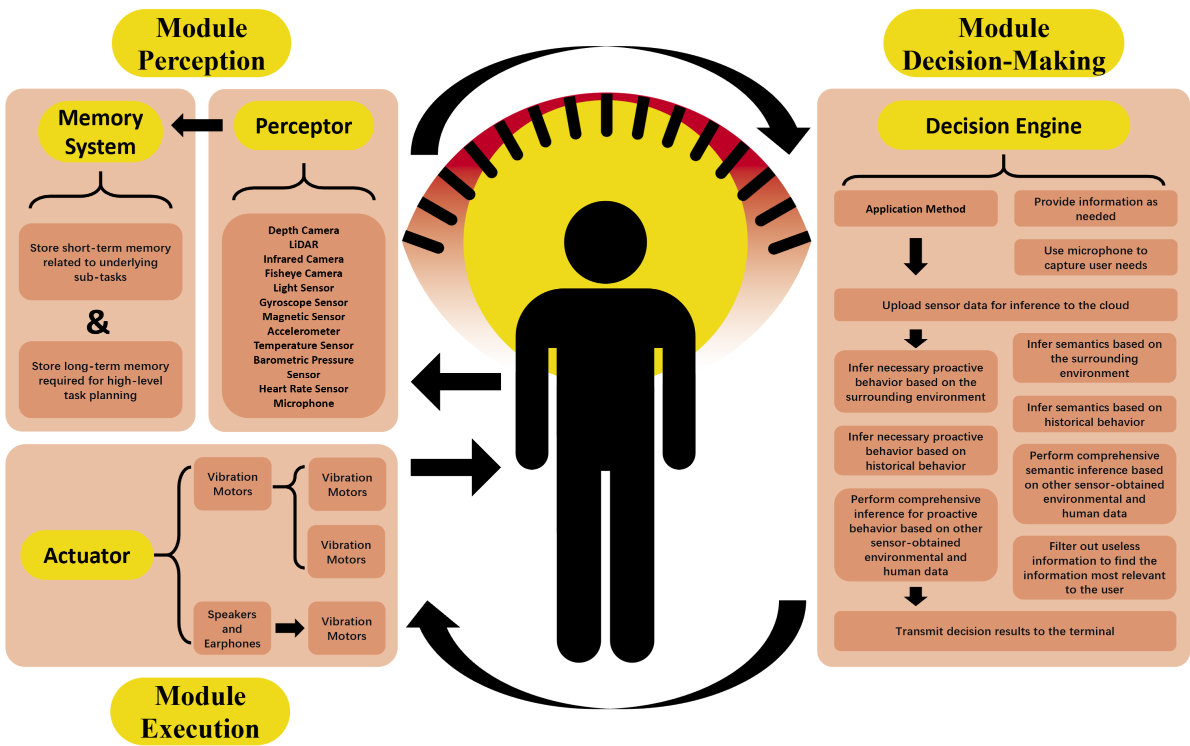

Figure 5. Framework of Embodied Intelligence and the Visually Impaired Population

5.1 Approach for Framework Development and Novelty

In constructing the framework for Embodied Intelligence in assistive technologies, the approach goes beyond traditional integration of perception, decision-making, and execution modules. Our framework innovates by introducing a dynamic feedback loop that allows for continuous learning and adaptation, a feature not commonly found in existing assistive technologies. This feedback loop enables the system to evolve with the user, becoming more attuned to their specific needs and environmental changes over time. The novelty lies in the system's ability to not just react to the immediate environment but to anticipate user needs and proactively adjust its support strategies. This proactive adaptation is a significant departure from static, one-size-fits-all solutions, offering a more personalized and effective assistive experience. To illustrate this framework, Figure 5 provides a schematic representation of the integrated modules and their interactions.

Furthermore, the framework should be scalable to accommodate future technological upgrades and additional functionalities. By adopting a systematic methodology, this framework can effectively realize the diverse applications of embodied intelligence, promoting social inclusion and independent living for visually impaired individuals.

Data collection for the study will involve both primary and secondary sources. Primary data will be gathered through interviews and surveys with visually impaired users to ensure reliability and validity. Secondary data will be sourced from relevant literature and technical reports to support the theoretical analysis.

5.2 Design Modular of the Framework

An efficient operation of complex systems relies heavily on a modular design. The embodied intelligence framework is structured into three primary components: the perception module, the decision-making module, and the execution module, each playing a crucial role in the overall system.

5.2.1 Module Perception

The perception module serves as the foundation of the framework, responsible for gathering and analyzing environmental information surrounding the user. This module integrates various sensors, including depth cameras, LiDAR, and infrared sensors, to capture comprehensive environmental data. By utilizing advanced image recognition and audio analysis technologies, this module can identify obstacles, pedestrians, and other critical elements in real-time, constructing a detailed environmental model. Additionally, the perception module must possess dynamic learning capabilities to optimize its performance based on user feedback and behavioral patterns, thereby enhancing the accuracy and efficiency of environmental understanding. The effective functioning of this module is vital for the decision-making module to generate intelligent decisions based on reliable data.

5.2.2 Module Decision-Making

As the core of the embodied intelligence framework, the decision-making module processes information received from the perception module and generates corresponding action plans. This module employs machine learning and deep learning algorithms to perform complex decision-making reasoning, taking into account both environmental information and the user’s historical behavior. It must exhibit adaptability, allowing it to adjust strategies in real-time to respond to changing environments and user needs. Furthermore, this module should evaluate various possible actions, conducting risk assessments and outcome analyses to determine the optimal execution strategy, ensuring user safety and convenience in diverse settings.

5.2.3 Module Execution

The execution module translates decisions into specific actions, ensuring that the system effectively implements the intended plans. This module utilizes various execution devices, such as vibration motors, speakers, and mobile manipulators, to provide multiple forms of feedback and interaction. The execution module must have a high response speed and flexibility, enabling it to quickly adapt to user commands and environmental changes. Additionally, it should feature a user-friendly interface, allowing users to control the system easily through voice commands or other interaction methods, thereby enhancing the overall user experience.

5.3 Mechanisms of Interaction and Feedback for Users in the Framework

Effective user interaction and feedback mechanisms are crucial components of the embodied intelligence framework, aimed at ensuring efficient communication between the user and the system by providing information both proactively and on demand.

5.3.1 Provision of Information Proactively

Regarding proactive information provision, the framework utilizes historical behavioral data alongside real-time environmental information to intelligently anticipate user needs. By analyzing users' routine activity patterns, the system can proactively deliver relevant information about the surroundings, such as obstacle locations, navigable paths, and important landmarks. This learning-based mechanism for pushing information can significantly enhance users' decision-making efficiency in dynamic environments while minimizing potential risks. Furthermore, users can adjust the content and frequency of information updates through simple voice commands or touch operations, thereby enhancing personalized experiences.

5.3.2 Provision of Information on Demand

The on-demand information provision mechanism delivers information in response to users' immediate requests. The system can swiftly identify user needs and, based on historical behaviors and environmental recognition, provide relevant information promptly. For instance, when a user requests navigation details to a specific location, the system generates the optimal action plan by combining the user's historical preferences with current environmental data. This mechanism not only enhances user engagement and sense of control but also facilitates effective two-way interaction between the user and the system, making the entire framework more flexible and adaptable.

6 POTENTIAL APPLICATIONS AND FUTURE PROSPECTS

6.1 Trends in Development for Embodied Intelligence Technology

The evolution of embodied intelligence technology is fostering its extensive application within the realm of assistive technologies. With advancements in sensors, artificial intelligence algorithms, and computational power, EI systems are becoming increasingly precise in their environmental perception and decision-making capabilities, enabling natural interactions between humans and machines. The convergence of these technologies points to a promising future for embodied intelligence in assistive technologies, offering substantial support to enhance the quality of life for visually impaired individuals.

6.2 Long-Term Effects on the BLV Population

Technologies rooted in embodied intelligence significantly enhance the independence of visually impaired individuals, allowing them to engage more confidently in social situations. By providing real-time environmental feedback and navigation support, these technologies improve mobility and foster a more positive societal perception of the potential of visually impaired individuals. This, in turn, encourages the development of relevant policies and social support systems.

6.3 Considerations Ethical and Acceptance Social

The promotion of embodied intelligence technology requires a strong focus on privacy protection and social acceptance. Developers must ensure data privacy is maintained during the design of EI devices, while also emphasizing accessibility and inclusivity to prevent creating dependency on technology among users. By implementing transparent ethical reviews and encouraging user participation, a sustainable environment for the development of assistive technologies can be established.

7 CONCLUSION

7.1 Key Research Findings Summary

This study presents a framework for integrating embodied intelligence within assistive technologies, emphasizing its potential applications for the visually impaired population. The findings suggest that multimodal perception and intelligent decision-making can offer personalized support to visually impaired individuals, providing a theoretical basis for future advancements in assistive technologies.

7.2 Directions for Future Research Recommendations

Future research should focus on improving the perceptual and decision-making capabilities of embodied intelligence systems and explore their applications across other disability domains. Empirical studies assessing user experience and social acceptance are essential to ensure its practicality and sustainability.

7.3 Impact Positive on the BLV Population and Social Importance

Technologies based on embodied intelligence have the potential to significantly enhance the confidence and independence of visually impaired individuals, facilitating their better integration into social life. The widespread adoption of such technologies will also contribute to improvements in related policies, fostering greater understanding and inclusivity for the visually impaired community within society.

REFERENCES

[1] De Vignemont, F. Embodiment, ownership and disownership. *Consciousness and Cognition*, 2011, 20(1), 82–93.

[2] Zbinden, J., Lendaro, E., and Ortiz-Catalan, M. Prosthetic embodiment: systematic review on definitions, measures, and experimental paradigms. *Journal of NeuroEngineering and Rehabilitation*, 2022, 19(1), 37.

[3] Engdahl, S.M., Meehan, S.K., and Gates, D.H. Differential experiences of embodiment between body-powered and myoelectric prosthesis users. *Scientific Reports*, 2020, 10(1), 15471.

[4] Hybart, R.L. and Ferris, D.P. Embodiment for robotic lower-limb exoskeletons: A narrative review. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 2022, 31, 657–668.

[5] Forte, G., Leemhuis, E., Favieri, F., Casagrande, M., Giannini, A.M., De Gennaro, L., and Pazzaglia, M. Exoskeletons for mobility after spinal cord injury: a personalized embodied approach. *Journal of Personalized Medicine*, 2022, 12(3), 380.

[6] Reza, A.B. and Danna G. A New Dataset Based on Images Taken by Blind People for Testing the Robustness of Image Classification Models Trained for ImageNet Categories. In *IEEE/CVF Conference on Computer Vision and Pattern Recognition*, 2023.

[7] Jin, D. and Zhang, L. Embodied intelligence weaves a better future. *Nature Machine Intelligence*, 2020, 2(11), 663–664.

[8] Gupta, A., Savarese, S., Ganguli, S., and Fei-Fei, L. Embodied intelligence via learning and evolution. *Nature Communications*, 2021, 12(1), 5721.

[9] Cecily M., Rita M., Martin G., Daniela M., Camilla L., Linda Y. W., and Edward C. Understanding Personalized Accessibility through Teachable AI: Designing and Evaluating Find My Things for People who are Blind or Low Vision. *International ACM SIGACCESS Conference on Computers and Accessibility*, 2023.

[10] Hughes, J., Abdulali, A., Hashem, R., and Iida, F. Embodied artificial intelligence: enabling the next intelligence revolution. In *IOP Conference Series: Materials Science and Engineering*, 2022, 1261(1), 012001.

[11] Cangelosi, A., Bongard, J., Fischer, M.H., and Nolfi, S. Embodied intelligence. In *Springer Handbook of Computational Intelligence*, 2015, pp. 697–714.

[12] Li, J., Li, Z., Chen, F., Bicchi, A., Sun, Y., and Fukuda, T. Combined sensing, cognition, learning, and control for developing future neurorobotics systems: a survey. *IEEE Transactions on Cognitive and Developmental Systems*, 2019, 11(2), 148–161.

[13] Liu, Y., Li, Z., Liu, H., Kan, Z., and Xu, B. Bioinspired embodiment for intelligent sensing and dexterity in fine manipulation: A survey. *IEEE Transactions on Industrial Informatics*, 2020, 16(7), 4308–4321.

[14] J. Hughes, A. Abdulali, R. Hashem, and F. Iida, "Embodied artificial intelligence: enabling the next intelligence revolution," in *IOP Conference Series: Materials Science and Engineering*, 2022, 1261(1).

[15] Xia, H., Zhang, Y., Rajabi, N., Taleb, F., Yang, Q., Kragic, D., and Li, Z. Shaping high-performance wearable robots for human motor and sensory reconstruction and enhancement. *Nature Communications*, 2024, 15(1), 1–12.

[16] Kalinowska, A., Pilarski, P. M., and Murphey, T. D. Embodied communication: How robots and people communicate through physical interaction. *Annual Review of Control, Robotics, and Autonomous Systems*, 2023, 6, 205–232.

[17] Fritsch, A., Lenggenhager, B., and Bekrater-Bodmann, R. Prosthesis embodiment and attenuation

of prosthetic touch in upper limb amputees–a proof-of-concept study. *Consciousness and Cognition*, 2021, 88, 103073.
[18] Segil, J. L., Roldan, L. M., and Graczyk, E. L. Measuring embodiment: A review of methods for prosthetic devices. *Frontiers in Neurorobotics*, 2022, 16, 902162.
[19] Lora-Millan, J. S., Sanchez-Cuesta, F. J., Romero, J. P., Moreno, J. C., and Rocon, E. Robotic exoskeleton embodiment in post-stroke hemiparetic patients: an experimental study about the integration of the assistance provided by the reflex knee exoskeleton. *Scientific Reports*, 2023, 13(1), 22908.
[20] Yang, J., He, Y., Shi, P., and Yu, H. A review on human intent understanding and compliance control strategies for lower limb exoskeletons. *Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering*, 2022, 236(6), 1067–1086.
[21] Tang, Q., Liang, J., and Zhu, F. A comparative review on multi-modal sensors fusion based on deep learning. *Signal Processing*, 2023, 109165.
[22] Zhang, Y.-P., Cao, G.-Z., Li, L.-L., and Diao, D.-F. Interactive control of lower-limb exoskeleton robots: A review. *IEEE Sensors Journal*, 2024.
[23] Nazari, F., Mohajer, N., Nahavandi, D., Khosravi, A., and Nahavandi, S. Applied exoskeleton technology: A comprehensive review of physical and cognitive human–robot interaction. *IEEE Transactions on Cognitive and Developmental Systems*, 2023, 15(3), 1102–1122.
[24] Diaz, M. A., Voss, M., Dillen, A., Tassignon, B., Flynn, L., Geeroms, J., Meeusen, R., Verstraten, T., Babic, J., Beckerle, P., et al. Human-in-the-loop optimization of wearable robotic devices to improve human–robot interaction: A systematic review. *IEEE Transactions on Cybernetics*, 2022, 53(12), 7483–7496.
[25] Tomás, D. J., Pais-Vieira, M., and Pais-Vieira, C. Sensorial feedback contribution to the sense of embodiment in brain–machine interfaces: A systematic review. *Applied Sciences*, 2023, 13(24), 13011.
[26] Heng, W., Solomon, S., and Gao, W. Flexible electronics and devices as human–machine interfaces for medical robotics. *Advanced Materials*, 2022, 34(16), 2107902.
[27] Park, J., Lee, Y., Cho, S., Choe, A., Yeom, J., Ro, Y. G., Kim, J., Kang, D.-H., Lee, S., and Ko, H. Soft sensors and actuators for wearable human–machine interfaces. *Chemical Reviews*, 2024.
[28] Zhang, L., Li, Z., Hu, Y., Smith, C., Farewik, E. M. G., and Wang, R. Ankle joint torque estimation using an emg-driven neuromusculoskeletal model and an artificial neural network model. *IEEE Transactions on Automation Science and Engineering*, 2020, 18(2), 564–573.
[29] Lara, J. E., Cheng, L. K., Röhrle, O., and Paskaranandavadivel, N. Muscle-specific high-density electromyography arrays for hand gesture classification. *IEEE Transactions on Biomedical Engineering*, 2021, 69(5), 1758–1766.
[30] Lee, H. S., Schreiner, L., Jo, S.-H., Sieghartsleitner, S., Jordan, M., Pretl, H., Guger, C., and Park, H.-S. Individual finger movement decoding using a novel ultra-high-density electroencephalography-based brain-computer interface system. *Frontiers in Neuroscience*, 2022, 16, 1009878.
[31] Cheng, J., Yang, Z., Overstreet, C. K., and Keefer, E. Fascicle-specific targeting of longitudinal intrafascicular electrodes for motor and sensory restoration in upper-limb amputees. *Hand Clinics*, 2021, 37(3), 401–414.
[32] Yang, L., Song, Y., Ma, K., and Xie, L. Motor imagery EEG decoding method based on a discriminative feature learning strategy. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 2021, 29, 368–379.
[33] Khosla, A., Khandnor, P., and Chand, T. A comparative analysis of signal processing and classification methods for different applications based on EEG signals. *Biocybernetics and Biomedical Engineering*, 2020, 40(2), 649–690.
[34] Delva, M. L., Lajoie, K., Khoshnam, M., and Menon, C. Wrist-worn wearables based on force myography: On the significance of user anthropometry. *BioMedical Engineering OnLine*, 2020, 19, 1–18.
[35] Cao, M. Y., Laws, S., and Baena, F. R. y. Six-axis force/torque sensors for robotics applications: A review. *IEEE Sensors Journal*, 2021, 21(24), 27238–27251.
[36] Nguyen X.-T.-A., Koopman J., van Genderen M.M., Stam H.L.M., and Boon C.J.F. Artificial vision: the effectiveness of the OrCam in patients with advanced inherited retinal dystrophies. *Acta Ophthalmologica*, 2021, 99(1), e50-e55.