

EURASIAN EXPERIMENT JOURNAL OF SCIENTIFIC AND APPLIED RESEARCH (EEJSAR)	ISSN: 2992-4146
©EEJSAR Publications	Volume 6 Issue 1 2024

# Smart Prosthetics: Integrating AI for Enhanced Mobility

Ariowachukwu Divine Sopruchi

Computer Engineering School of Engineering and Applied Sciences Kampala International University Uganda

## ABSTRACT

This paper examines the transformative role of artificial intelligence (AI) in the field of prosthetics, specifically focusing on the development of smart prosthetic devices designed to enhance mobility, adaptability, and user autonomy. Traditional prosthetic devices have provided functional mobility but lack the intuitive and adaptive qualities necessary for complex movement. With advancements in machine learning and sensor technology, smart prosthetics now offer users a more natural and customized experience. The study reviews the design principles, AI integration methods, and user-centered approaches in the development of intelligent prostheses. Challenges such as cost, user training, and technical limitations are also discussed alongside opportunities for future advancements. Case studies are included to showcase recent innovations, highlighting the interdisciplinary collaboration driving the field forward. The paper concludes with future trends in AI-enhanced prosthetic development, which aim to improve the physiological health and psychological well-being of amputees.

**Keywords:** Smart Prosthetics, Artificial Intelligence, Machine Learning, User-Centered Design, Prosthetic Mobility.

## INTRODUCTION

Prosthetic devices are used to replace parts of the body lost to injury, disease, or disorder. Prosthetics aims to allow users to lead a normal life with as little loss of mobility as possible. They not only improve bodily functions like walking, running, and gripping but also enhance a person's psychological well-being by helping them regain an aesthetic appearance and their self-esteem. Using mechatronic engineering, a limb replacement can be made according to a patient's physiological needs and lifestyle requirements. It is also possible to provide replacements with added artificial features, such as strength or sensory feedback. Historically, prosthetic limbs were developed more than 3,000 years ago. However, prosthetics as we know them came into existence in the mid-20th century, and the technology has slowly evolved. Traditional prosthetics primarily served to help individuals walk by mechanically replicating the functions of the replaced limb. Most prosthetics available today are still based on this basic setup. Smart prosthetics, however, aim to improve the quality of life further by providing active support during mobility as add-ons [1, 2]. User-centered design determines the goals of an intelligent human-centered prosthetic device. Instrumented prosthetic feet and knees, which can adjust to changes in terrain or walking speed, have been a stepping stone for intelligent prosthetic development. New sensors and digital tools have enabled the prostheses to 'listen' and 'understand' through pattern recognition and offer sophisticated control for individual leg movement. The results are promising, with the new ankle and knee mechanisms offering more natural walking patterns and enhanced stability. It is also very possible to integrate artificial intelligence so that the user has to think less about coordinating with the prosthesis, making life even easier. The concept is seen as a technological breakthrough, especially for individuals who have had a lower-limb amputation, but the challenges brought by the development of devices that span different environments and the agility of the human body are very complex [3, 4].

### The Role of Artificial Intelligence in Prosthetic Devices

Apart from extraordinary speed, the true capabilities of AI reside in its adaptive learning techniques. Machine learning allows the study of AIs' "past behaviors" to predict the movements of any prosthetic

user. This results in the possibility to adapt AI's behavior to the needs of the user. The automation of this process is a fundamental feature to develop smart prosthetics with the capability "to become intelligent" by themselves, through the continuous optimization of learning algorithms. The evolution of sensors and machine learning techniques has been the catalyst in the replacement of traditional control strategies of the current generation of commercially available smart prosthetics. These devices require an initial training phase, usually lasting several weeks, where AI's behavior is personalized according to the patient's walking pattern [5, 6]. Just like the human brain acquires experience over time, AI-driven prosthetics now possess gait recognition and performance enhancement capabilities. The data coming from IMUs can be exploited in the calibration and the learning phase. During the calibration, users have to walk a large number of steps, and their gait is captured. This training phase is crucial because the users wearing prostheses should use them and walk with them to "train the AI". The amount of data collected through this phase is essential to properly drive the optimization of the algorithms implemented in the prostheses. Each commercial smart prosthetic, as well as the gait recognition system, uses AI. The training dataset used to tune or learn the AI's behavior is collected and well represents the target population of the prostheses in terms of age, weight, gender, and other parameters. Only in this way, the AI will be able to respond in the correct way to the user's needs [7, 8].

### **Challenges and Opportunities in Integrating AI with Prosthetics**

Despite these exciting advances, integrating AI and robotics with prosthetics in replaceable and smart ways is technically challenging. Robotic prosthesis development is faster, more agile, and more data-driven than software updates or OS fixes, and the rest of the technological ecosystem, such as connectors and hardware designs, must adhere to comparable schedules. While companies' software capabilities and medical and healthcare sector incompatibility present technical challenges, high cost is a third obstacle to accepting AI- and robotic-based products. Those with better insurance protection and financial means may profit from such sophisticated and personalized health tools. Despite these challenges, several opportunities exist. Smart prosthetic devices make a user's life easier and more convenient. When it comes to wearable robotics, some researchers stress the importance of bringing together a multidisciplinary team of engineers, healthcare professionals, or users to establish the perfect device that fits seamlessly into the wearer's life. The use of AI in some prosthetic devices has the potential to help a person walk or move independently and more effectively. Regulatory best practices, security, reliability, and aftermarket service are important factors to consider, as they are for all AI- or smart prosthetic devices. Future research should investigate the consequences of these obstacles, as research has the potential to transform smart prosthetics and those who rely on them. Overall, we need to accept that we are balancing two extreme silos, one of which is technology push and the other is demand-pull. While it's easy to be overly enthusiastic about current AI or robotic prosthetics, it's critical to avoid diminishing the possibility they provide in the not-too-distant future [9, 10].

### **Case Studies and Innovations in Smart Prosthetics**

Smart prosthetics that integrate AI technologies have been designed and developed by researchers and private companies around the world. While not exhaustive, this list highlights some state-of-the-art prosthetics and how they are changing the lives of their users. These innovations are the result of industry-academia collaboration, as private companies team up with research institutes and national universities for the co-development of technology. Smart prostheses, even those that utilize AI, are often prized for their novelty and being the first of their kind in the world. Many areas of prosthetic research must be conducted by professionals, though this is slowly changing as work to understand user-based research and its applications is being translated into business communication [10, 11]. Japanese researchers from a joint industry-academia team succeeded in creating a multi-material 3D-shaped prosthetic heel for a 22-year-old recreational runner with the most advanced 3D printing technology. A Japanese company has completed the development of a smart lower-limb wearable robotic suit and neuroprosthetic device. The creators of the 3D-printed robotic hand have developed a complete prosthesis that includes a bionic hand, back, and exchangeable arms for disabled use. The hand prosthetic has two versions: a field trial and a trial that includes the back. Users have given feedback on the hand trial, with a 56-year-old woman who lost her right hand in an accident saying: "It is wonderful that prosthetic hands are getting closer to human capability." A Japanese robotics company showcased a new medical device called the Pneumatic Powered Lower Limb Prosthetic Device. The 4 kg device includes an AI chip that takes one month to learn each user's natural motion and gait, helping to improve freedom of movement and decreasing walking load on anyone in any environment. The prosthetic received an Innovation

Awards Honoree in the Health & Wellness category. A Japan-based technology has developed an external prosthesis using stimuli-responsive materials, recently releasing a prototype with a major design overhaul [12, 13].

### Future Trends and Implications

The prosthetic field also follows the trends of materials science and other areas. Developing new materials, particularly composites of some kind, is one such line of development. Lighter, more physiologically compliant implants are also possible [14-16]. On the algorithm side, the development of AI that enables the system to predict users' intentions and develop a personalized control strategy will have great potential in artificial prostheses [17-19]. Passive bionic and AI-enhanced smart systems will be developed, which will deliver smarter services to users. Future prosthetic users will have many different AI-enhanced prosthetic feet to choose between [20-21]. At least two parallel worlds of prosthetic feet will coexist. Some users will opt for the simplest, dumbest feet because they are the cheapest and least personally intrusive. Other users will opt for smart feet, the control of which closely matches their feeding requirements, giving them maximum amputee body function [22-24]. While the AI approach is developing, there are also interesting basic questions for researchers. We believe these to be: Can we make a foot 'will itself what to do,' with an element of a broad, generalist, and perhaps reactive capability? If someone kicks a soccer ball towards me, for example, my foot can sense the brush of wind against the side of the ball and consequently 'will itself' to either lean to prevent the ball from missing the sole by going under it, or stand off the ground to press down on the flooring foot platform in an attempt to provide some initial rollover that will stop the operative foot from being grounded at zero speed [25-25]. Whatever the broad, general answers to these questions, of course, some detailed ones will have to be prosthesis or orthopedic foot specific. More practically, we need to implement the DDEAs to establish the reality of a smart ankle prosthesis and gain formative user feedback on their acceptability. We feel highly confident that the outcome of this work will be of significant benefit to individual dysvascular lower limb amputees' mobility, and ultimately their psychosocial integration and physiological health for a considerable period into the future [26-27]. By developing a smart ankle prosthesis prototype, we can enable the development of the AI system for powered prostheses. The smart ankle could leverage our existing gait adaptive prototype such that it uses the planning component and the discrete VCFs. We know that augmented feedback has been shown to improve motor control and learning, so it would be interesting to also test the augmented feedback we can implement in the initial smart ankle implementation. Therefore, we can demonstrate a number of ways that the smart ankle prosthesis can be seen as a stepping-stone project to developing smart powered prosthetic technologies. Our prosthesis is crosswalk prototype 1. 2-Degree of Freedom, one degree of freedom driving with a linear actuator with a rated torque of 350 Nm, and the second degree of freedom with a gas spring with interchangeable units of restitution and torque of 150 Nm. These innovative materials required the development of a dedicated framework to control the actuator in order to adapt its behavior according to users' output, which had data acquisition, embedded communication suite, and host-side software to perform tuning and simulation tests of the actuator dynamics with the target to test the influence of materials and the footprint on the energy transfer involved during gait in the physical walking background device [22-27].

### CONCLUSION

The integration of AI in prosthetics marks a significant step forward in mobility assistance technology, enabling amputees to experience a higher degree of functionality and independence. Smart prosthetics equipped with adaptive algorithms and advanced sensors have shown the potential to offer real-time responsiveness and personalized support. Despite current challenges, such as high costs and the need for extended user training, the advancements in AI-driven control systems and materials science suggest a promising future for intelligent prosthetic development. Continued research, particularly on refining adaptive algorithms and enhancing affordability, will play a crucial role in making these advanced prosthetics accessible to a broader range of users. By focusing on user-centered design and interdisciplinary collaboration, the prosthetic industry is poised to significantly improve the quality of life and mobility for those with limb loss, ultimately supporting their social integration and mental well-being.

### REFERENCES

1. Gaeb AK, Hussein AA, Ismael AS, Khader MD, Khalaf Ma. Advancements In Medical Devices For Skin Beautification. European Journal Of Modern Medicine And Practice. 2024 Sep 4;4(9):108-21.

2. Pandelea M, Todirițe I, Radu Frenț C, Vlădăreanu L, Iliescu M. Integrated Smart System for Robotic Assisted Living. In Sustainable Intelligent Systems 2021 Mar 7 (pp. 147-160). Singapore: Springer Singapore. [\[HTML\]](#)
3. Cabrera IA, Pike TC, McKittrick JM, Meyers MA, Rao RR, Lin AY. Digital healthcare technologies: Modern tools to transform prosthetic care. *Expert Review of Medical Devices*. 2021 Dec 3;18(sup1):129-44. [techrxiv.org](https://techrxiv.org)
4. Ochsner B, Spöhrer M, Stock R. Rethinking assistive technologies: users, environments, digital media, and app-practices of hearing. *Nanoethics*. 2022 Apr 1:1-5.
5. Ahmad R, Wazirali R, Abu-Ain T. Machine learning for wireless sensor networks security: An overview of challenges and issues. *Sensors*. 2022 Jun 23;22(13):4730.
6. Sun L, You F. Machine learning and data-driven techniques for the control of smart power generation systems: An uncertainty handling perspective. *Engineering*. 2021 Sep 1;7(9):1239-47.
7. Katmah R, Al Shehhi A, Jelinek HF, Hulleck AA, Khalaf K. A Systematic Review of Gait Analysis in the Context of Multimodal Sensing Fusion and AI. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*. 2023 Oct 17.
8. Wang C, He T, Zhou H, Zhang Z, Lee C. Artificial intelligence enhanced sensors-enabling technologies to next-generation healthcare and biomedical platform. *Bioelectronic Medicine*. 2023 Aug 2;9(1):17.
9. Tan Q, Wu C, Li L, Shao W, Luo M. Nanomaterial-Based Prosthetic Limbs for Disability Mobility Assistance: A Review of Recent Advances. *Journal of Nanomaterials*. 2022;2022(1):3425297
10. Asif M, Tiwana MI, Khan US, Qureshi WS, Iqbal J, Rashid N, Naseer N. Advancements, trends and future prospects of lower limb prosthesis. *IEEE Access*. 2021 Jun 7;9:85956-77. [ieeexplore.ieee.org](https://ieeexplore.ieee.org)
11. Elcadi GH. Advancements and Challenges in Prosthetic Devices: Exploring Materials, Integration, and Future Directions. *Journal of Disability Research*. 2023 Jun 2;2(1):i-
12. Han R, Koo SH. Big data analyses on key terms of wearable robots in social network services. *International Journal of Clothing Science and Technology*. 2022 Mar 11;34(2):285-98. [\[HTML\]](#)
13. Bhardwaj S, Khan AA, Muzammil M. Lower limb rehabilitation robotics: The current understanding and technology. *Work*. 2021 Jan 1;69(3):775-93.
14. Sun Y, Tang H, Tang Y, Zheng J, Dong D, Chen X, Liu F, Bai L, Ge W, Xin L, Pu H. Review of recent progress in robotic knee prosthesis related techniques: Structure, actuation and control. *Journal of Bionic Engineering*. 2021 Jul;18(4):764-85. [springer.com](https://www.springer.com)
15. Alvarado-Landeo I, Surichaqui-Montalvo E, Velasquez-Colorado K, Huamanchahua D. Artificial intelligence applied in Human Medicine with the implementation of prostheses. In 2022 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS) 2022 Jun 1 (pp. 1-7). IEEE. [\[HTML\]](#)
16. Sensinger JW, Dosen S. A review of sensory feedback in upper-limb prostheses from the perspective of human motor control. *Frontiers in neuroscience*. 2020 Jun 23;14:345.
17. Gil MJ, Gonzalez-Medina G, Lucena-Anton D, Perez-Cabezas V, Ruiz-Molinero MD, Martín-Valero R. Augmented reality in physical therapy: systematic review and meta-analysis. *JMIR Serious Games*. 2021 Dec 15;9(4):e30985.
18. Enerst, E., Eze, V. H. U., Ibrahim, M. J., & Bwire, I. Automated Hybrid Smart Door Control System. *IAA Journal of Scientific Research*, 2023. 10(1), 36-48
19. Enerst, E., Eze, V. H. U., Musiimenta, I., & Wantimba, J. Design and Implementation of a Smart Surveillance Security System. *IDOSR Journal of Science and Technology*, 2023. 9(1), 98-106. <https://doi.org/10.5120/cae2020652855>
20. Enerst, E., Eze, V. H. U., Okot, J., Wantimba, J., & Ugwu, C. N. DESIGN AND IMPLEMENTATION OF FIRE PREVENTION AND CONTROL SYSTEM USING ATMEGA328P MICROCONTROLLER. *International Journal of Innovative and Applied Research*, 2023. 11(06), 25-34. <https://doi.org/10.58538/IJIAR/2030>
21. Enerst, E., Eze, V. H. U., & Wantimba, J. Design and Implementation of an Improved Automatic DC Motor Speed Control Systems Using Microcontroller. *IDOSR Journal of Science and Technology*, 2023. 9(1), 107-119.

22. Enyi, V. S., Eze, V. H. U., Ugwu, F. C., & Ogbonna, C. C. Path Loss Model Predictions for Different Gsm Networks in the University of Nigeria, Nsukka Campus Environment for Estimation of Propagation Loss. *International Journal of Advanced Research in Computer and Communication Engineering*, 2021. 10(8), 108–115. <https://doi.org/10.17148/IJARCCCE.2021.10816>
23. Eze, M. C., Eze, V. H. U., Chidebelu, N. O., Ugwu, S. A., Odo, J. I., & Odi, J. I. NOVEL PASSIVE NEGATIVE AND POSITIVE CLAMPER CIRCUITS DESIGN FOR ELECTRONIC SYSTEMS. *International Journal of Scientific & Engineering Research*, 2017. 8(5), 856–867.
24. Eze, M. C., Eze, V. H. U., Ugwuanyi, G. N., Alnajideen, M., Atia, A., Olisa, S. C., Rocha, V. G., & Min, G. Improving the efficiency and stability of in-air fabricated perovskite solar cells using the mixed antisolvent of methyl acetate and chloroform. *Organic Electronics*, 2022 107, 1–10. <https://doi.org/10.1016/j.orgel.2022.106552>
25. Eze, M. C., Ugwuanyi, G., Li, M., Eze, V. H. U., Rodriguez, G. M., Evans, A., Rocha, V. G., Li, Z., & Min, G. Optimum silver contact sputtering parameters for efficient perovskite solar cell fabrication. *Solar Energy Materials and Solar Cells*, 2021 230(2020), 111185. <https://doi.org/10.1016/j.solmat.2021.111185>
26. Eze, V. H. U. Development of Stable and Optimized Bandgap Perovskite Materials for Photovoltaic Applications. *IDOSR Journal of Computer and Applied Science*, 2023 8(1), 44–51.
27. Eze, V. H. U. Advancing Sustainable Energy Solutions in Uganda: A Comprehensive Exploration for Multi-Source Power Control Design. *IAA Journal of Applied Sciences* 2024. 11(1):73-86, 11(1), 73–86.

**CITE AS: Ariowachukwu Divine Sopruchi. (2024). Smart Prosthetics: Integrating AI for Enhanced Mobility. EURASIAN EXPERIMENT JOURNAL OF SCIENTIFIC AND APPLIED RESEARCH, 6(1):25-29**