An Integrated BCI-Exoskeleton Adaptive Multi-Functional Walking Rehabilitation Robot

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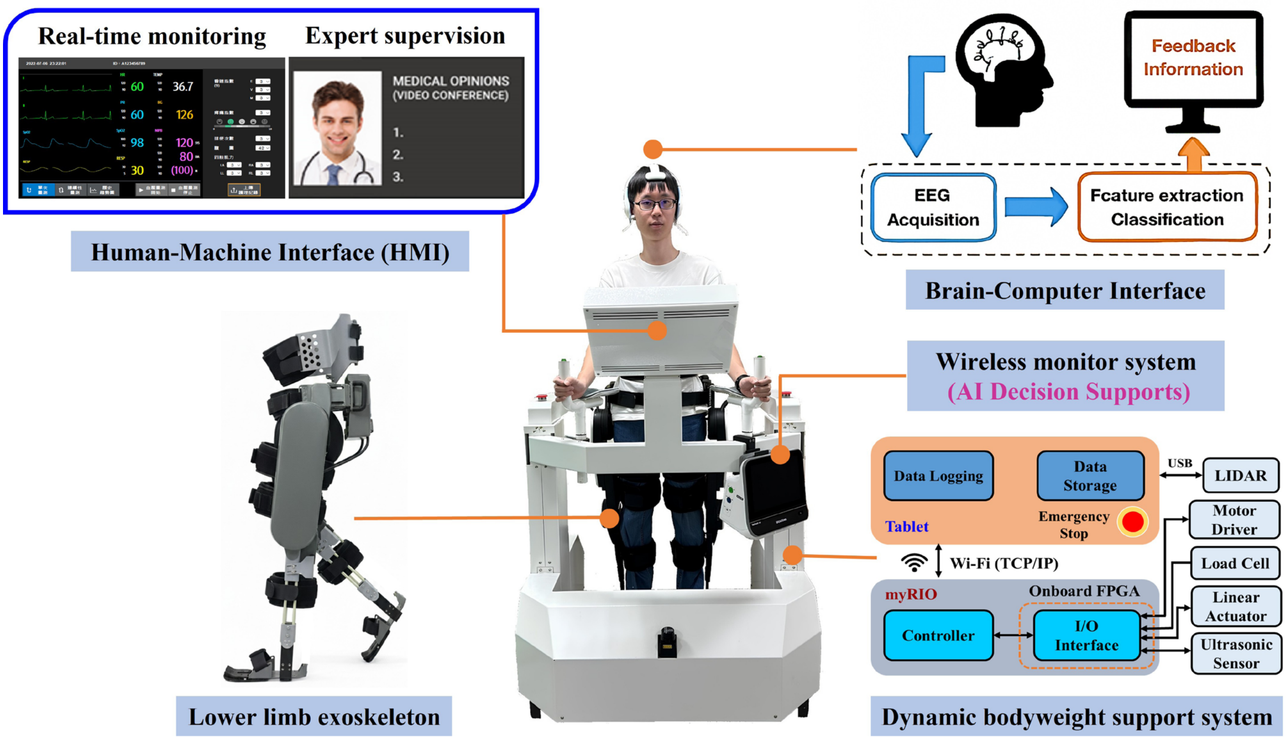
Group photograph of the interdisciplinary research team at the National Science and Technology Council (NSTC)

Addressing the critical challenges of an aging global population and the limitations of traditional rehabilitation, our study has demonstrated pioneering advancements in intelligent robotic healthcare. Through this interdisciplinary initiative, we collaborated with National Yang Ming Chiao Tung University (NYCU) and Kaohsiung Medical University (KMU) for over a decade, successfully integrating neural engineering with robotics to develop "HopeStride", the world's first Brain-Reading AI-Driven Walking Rehabilitation Robot. By bridging the gap between academic research and clinical application, this study aims to alleviate the heavy physical burden on therapists while significantly enhancing clinical efficiency for rehabilitation physicians.

One of the study's most impactful outcomes is the establishment of a "Central-Peripheral-Central" closed-loop training architecture. Unlike conventional devices that provide only passive mechanical support, HopeStride employs a cutting-edge three-phase adaptive protocol: (1) standing and balance assistance, (2) vision-assisted gait guidance, and (3) active "intention-controlled walking". This system analyzes EEG signals to interpret motor intentions, actuating the lower-limb exoskeleton only when the patient actively initiates a command. This approach effectively synchronizes walking intention with physical execution, fostering true neural remodeling rather than simple passive movement.

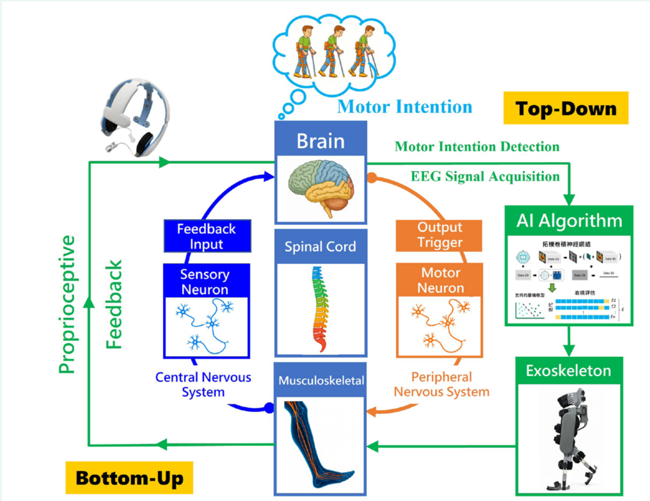


Multifunctional Gait Training and Walking Assistance Robot

In clinical applications, the study has achieved significant breakthroughs validated at KMU Chung-Ho Memorial Hospital. A comparative study spanning 20 treatment sessions revealed that patients utilizing this BCI-driven system showed concurrent improvements in both lower-limb function and cardiopulmonary endurance, whereas control groups receiving passive training improved primarily in limb function alone. These results substantiate that "brain-driven rehabilitation" simultaneously strengthens physiological and neural systems, yielding dual benefits that traditional methods cannot achieve.

Overall, HopeStride represents a paradigm shift from passive therapy to active, neural-integrated rehabilitation. By successfully combining AI, BCI, and robotics, this research not only addresses urgent clinical manpower gaps but also establishes a new benchmark for smart medicine, empowering patients to reclaim their mobility and shaping the future of neurorehabilitation.

The HopeStride System & Innovative Breakthroughs



"Central-Peripheral-Central" Closed-Loop Training Mechanism

Research Highlights

1. 2025 NSTC Control Engineering Program Research Project Achievement Award, Highest Distinction
2. 2024 NSTC Future Tech Award
3. 2024 Taiwan Innotech Expo (TIE) Invention Competition, Platinum Medal
4. 2023 National Innovation Award

Research Output

1. Lee, L.-W., Li, I.-H., & Liang, T.-W. (2021). A proof of concept study for the design, manufacturing, and control of a mobile overground gait-training system. *International Journal of Fuzzy Systems, 23*(8), 2396–2416. https://doi.org/10.1007/s40815-021-01051-8
2. Lee, L.-W., & Li, I.-H. (2025). Safety-enhanced control for a MuscleDrive waist-assistive exoskeleton. *Control Engineering Practice, 156,* 106182. https://doi.org/10.1016/j.conengprac.2024.106182
3. Lee, L.-W., Wang, S.-T., & Li, I.-H. (2025). An IoT-enabled omnidirectional mobile system for home-based rehabilitation of upper and lower limbs. *Internet of Things, 30,* 101525. https://doi.org/10.1016/j.iot.2025.101525