A Dual-Degree-Freedom Ankle-Foot Rehabilitation Device Equipped With AI and Based on Artificial Pneumatic Muscles to Assist Walking by Adapting the Gait

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To address the limitations of existing ankle-foot rehabilitation devices in dynamic adaptability, response speed, and control accuracy, presents an upgraded intelligent rehabilitation system based on a pneumatic muscle driving unit integrated with adaptive machine learning and structural optimization. The device retains a dual-degreeof-freedom mechanism to enable dorsiflexion/plantarflexion and inversion/eversion, utilizing four lightweight pneumatic artificial muscles as actuators for enhanced stability during dorsiflexion. A multi-modal gait data acquisition system incorporating MPU6050, plantar pressure sensors enables real-time gait phase recognition via a locally deployed machine learning model on an ESP32-S3 microcontroller, achieving a response latency of =100 ms through predictive control. Structurally, a full-enveloping exoskeleton frame improves wearing stability and adaptability, while noise reduction measures and a data visualization interface support rehabilitation progress assessment. The system supports automatic, manual, and adaptive modes, enabling intelligent assistance and training. This work offers an efficient, precise, and comfortable solution for ankle-foot rehabilitation through integrated sensing, adaptive control, and optimized structure.

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