An Integrated Robotic System With EEG Intent Recognition for Customizable Home-Based Upper Limb Rehabilitation

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Upper limb impairment resulting from neurological conditions such as stroke often reduces quality of life and requires ongoing rehabilitation. However, access to rehabilitation is often limited by cost or location. Thus, this project aims to design and build a biomedical rehabilitation device prototype that enables safe, accessible, and customizable rehabilitation for patients in a home setting. The device integrates neurology and engineering to create a prototype. The device integrates a spherical parallel manipulator to facilitate multi-axis wrist motion simulation and a system of three linear actuators to simulate arm flexion and extension. To enhance customizability and accuracy, an electroencephalography intent recognition module was added to the noninvasive modules, which, together with an analog-digital system, acquire neural signals from the brain. A support vector machine classifier is trained to specifically identify an individual’s intent, varying from arm extension to motor imagery states. The closed-loop control framework uses decoded neural signals while preserving the ability to override manually. Altogether, these functions underwent thorough testing, enabling precise evaluation of the device's capabilities. After comprehensive testing, the device achieved a maximum flexion angle of 66 degrees, a maximum pull force of 46 newtons, and smooth wrist motion simulation. The EEG module successfully classified motor imagery states after exhaustive training. These demonstrations of the systems enable reliable patient-triggered rehabilitation. This study demonstrates the feasibility of integrating intent recognition into an accessible and engineered arm rehabilitation device. The system exhibits potential for future adaptive control optimization.

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