NeuroFlex: A Cost-Effective, Non-Invasive EEG-Controlled Bionic Prosthesis for Transfemoral Amputees

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Current lower limb prostheses rely on cumbersome procedures, need risky surgery, and are prohibitively expensive. As a result, many lower-limb amputees experience unnatural gait patterns and excessive energy expenditure, leading to discomfort and long-term health complications. To address these challenges, we developed NeuroFlex, a low-cost, non-invasive EEG-controlled transfemoral bionic prosthesis that integrates a machine-learning-based control system, a three-degree-of-freedom (DoF) ankle mechanism, and quasi-direct drive (QDD) actuators for dynamic movements. Our system starts with a multi-step process that combines EEG signals with IMU-based analysis. First, EEG signals are filtered, reducing interference. Next, IMUs detect gait cycle changes, improving adaptation. A hybrid machine learning model extracts movement features through a spike-frequency method, classifying user intent with 98.67% accuracy. Finally, an active loop continuously refines movements, reducing energy expenditure by 35% compared to conventional prostheses. Our engineering innovations enhance natural movement by utilizing QDD actuators for precise joint control and an ankle angular suspension mechanism to improve balance and mobility. Constructed with robust materials and ML-centered processing chips, NeuroFlex remains cost-effective at $1,000, making it significantly more accessible than commercial bionic prostheses priced at around $100,000. During industry-standard tests, NeuroFlex achieved a response latency of 0.04 seconds, 99.7% stride accuracy, and multi-axis movement capabilities. NeuroFlex combines high-accuracy subconscious control, adaptive gait mechanics, and accessible multivariate DoF engineering, offering a practical and affordable solution for the lower limb prosthetics market.

Awards Won: