AlphaHand: Individual Finger Movement Identification Using CNN/LSTM From Consumer Grade EEG

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Approximately 2.1 million people in the U.S. live with limb loss, with about 36% experiencing depression. Conventional non-invasive prosthetic control relies on electromyography (EMG), which requires residual muscle activity and excludes individuals with congenital limb deficiency, while implant-based interfaces offer higher precision but carry surgical risk. No EEG-based prosthetic systems are currently available at scale in the U.S. This project investigates whether consumer-grade wearable EEG can decode individual finger motor execution (ME) and translate those signals into real-time control of a five-finger robotic hand. EEG data was collected using a 4-channel Muse 2 headband sampled at 256 Hz and labeled via time-aligned event markers. The pipeline combines sliding-window preprocessing (window: 0.25 s, hop: 0.05 s) with a multi-head CNN+LSTM classifier and uncertainty-aware evaluation via Monte Carlo (MC) dropout and softmax. Inferred ME signals drive servo motors through an Arduino microcontroller, enabling live finger actuation. Among two subjects, the best-performing subject-specific model achieved 89.79% held-out test action accuracy and 87.01% non-REST finger accuracy. Deployment-style evaluation yielded 84.66% joint accuracy, while pseudo-live replay yielded 91.75% committed action accuracy and 93.32% non-REST precision among commands that would have been sent for actuation. Calibration was assessed using expected calibration error (ECE), with action ECE of 0.0232 and non-REST finger ECE of 0.0273. These results demonstrate the feasibility of subject-specific finger-level prosthetic control using low-cost wearable EEG, offering a pathway for individuals with congenital limb deficiency and others excluded from EMG-based systems.

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