The Pain-Aware Exoskeleton: A Lower Body Assistive System With Integrated BCI for Real-Time Pain Assessment

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This project involved designing and testing a lower-limb exoskeleton integrated with a brain-computer interface (BCI). Its objective was to address the physiological, psychological, and social problems brought by degenerative illnesses like osteoarthritis by achieving real-time evaluation of the user's pain level and adjusting the exoskeleton's response accordingly. Brain activity changes that indicate pain are read through non-invasive electroencephalogram (EEG) signals and movement intentions are collected as surface electromyography (EMG) signals. Regarding hardware, a wire-driven joint structure was designed and MG4010E-i36 servo motors were used as drive units. Software-wise, the OpenBCI platform was used to collect and interpret EEG and EMG signals, while EEGLAB was used for signal analysis for 3 different classified pain levels. Numerical data was collected and analysed for 11 selected EEG channels for all 3 pain levels. Experimental results showed that specific brain regions (e.g. C3, C4, F8) show measurable response characteristics to pain stimuli, and can be used as effective indicators for pain recognition. Although limitations have been identified regarding the generalizability of the results, this study validates the engineering feasibility of integrating BCI devices with a custom-built exoskeleton system and provides a prototype foundation for future personalized assistive devices targeting patients with degenerative diseases.

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