EEG-based Control of a Robotic Hand

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Objective

- Build a brain-computer interface (BCI) that bypasses muscular activity to control a robotic hand, using EEG signals through a trained support-vector machine (SVM) classifier, to assist/improve motor rehabilitation for patients with MND

Background

- Motor neuron disease (MND) is neurological disorder that destroys motor neurons over time, and leads to loss of motor functions (difficulty in moving around, breathing, etc.). It commonly affects people in their 60s to 70s, but it can affect people of all ages.
- There's no cure for MND. Current treatments such as physical therapy or medication (Riluzole, botulinum toxin, etc.) help reduce the impact it has on a person's daily life.

Methods

- Record neural activity and muscle activity (reference to find EEG marker and evaluate the accuracy), feed data into SVM classifier of BCI model, and send the corresponding motion produced to the robotic hand.
- SVM: Choose threshold to pinpoint within the EEG signal to determine the subject's desired movement. Utilize α-power reduction threshold, which reduces when movement is detected in an EEG signal. Epochs (time stamps from before and after an event) are extracted where an event related desynchronization (ERD) was found. An ERD can be quantitatively defined (Fig. 1).

$$ERD = \frac{At - Ao}{Ao}$$

Ao = baseline alpha-power before event
At = alpha-power relative to the baseline during/following the event

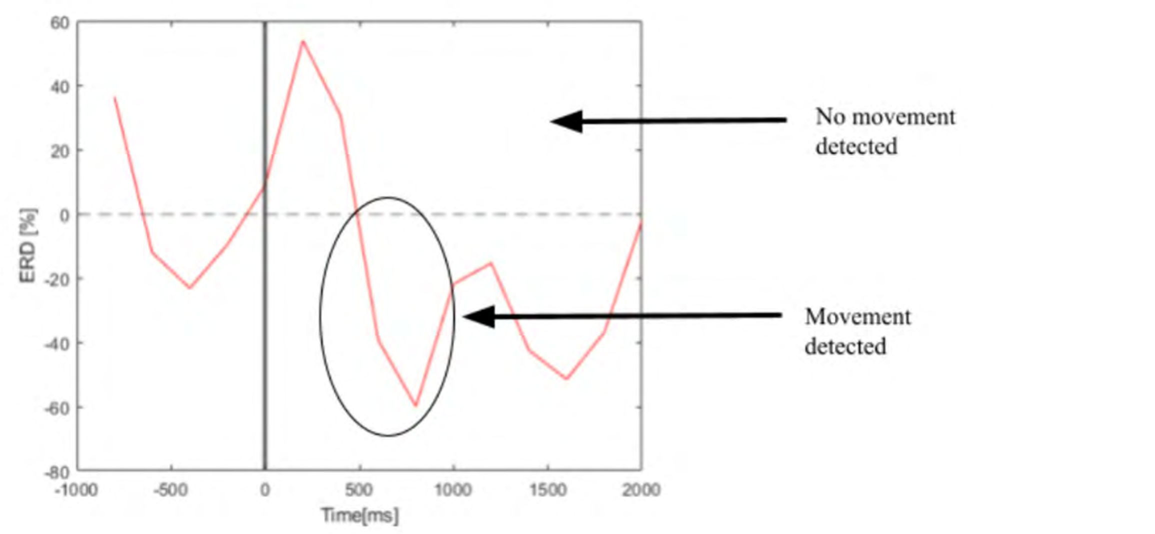

Figure 1. Event related desynchronization equation and an example of an ERD. A negative percentage corresponds to movement, while a positive ERD percentage corresponds does not.

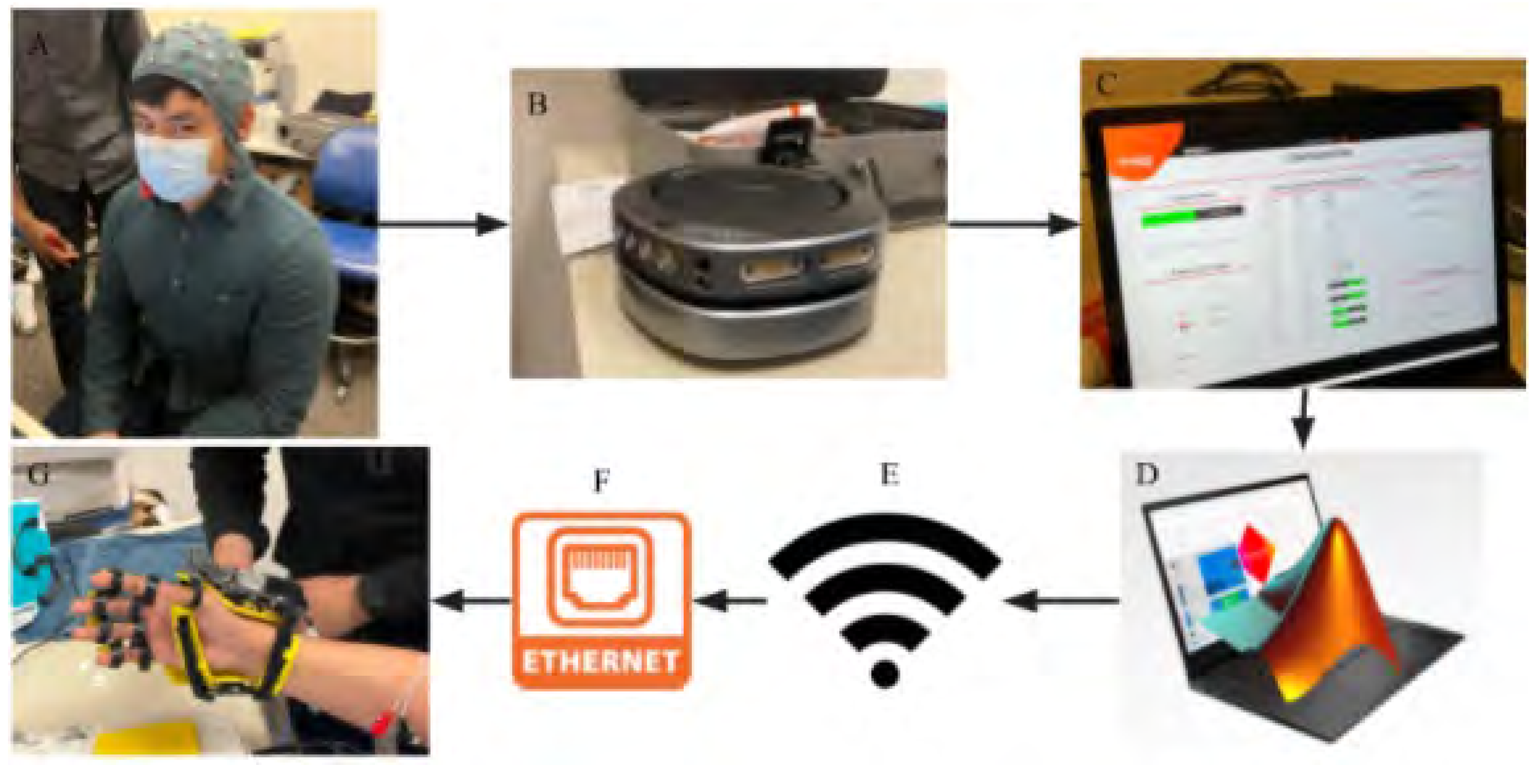

Figure 2. The images A-G show the workflow of the designed brain-machine interface.

A. EEG Cap: Collects alpha wave information
B. TMSi amplifier: Magnifies wave amplitudes
C. TMSi software: visualizes the EEG signals as they're being recorded.
D. MATLAB SVM: binary classifier between movement and no movement.
E-F. Wireless connection to ethernet hub.
G. Hand of Hope: wireless robotic hand.

- Recording day involved our teammate performing a series of fifty hand-squeeze motions in intervals of 10 seconds. This provided both EMG and EEG data to train the classifier with.

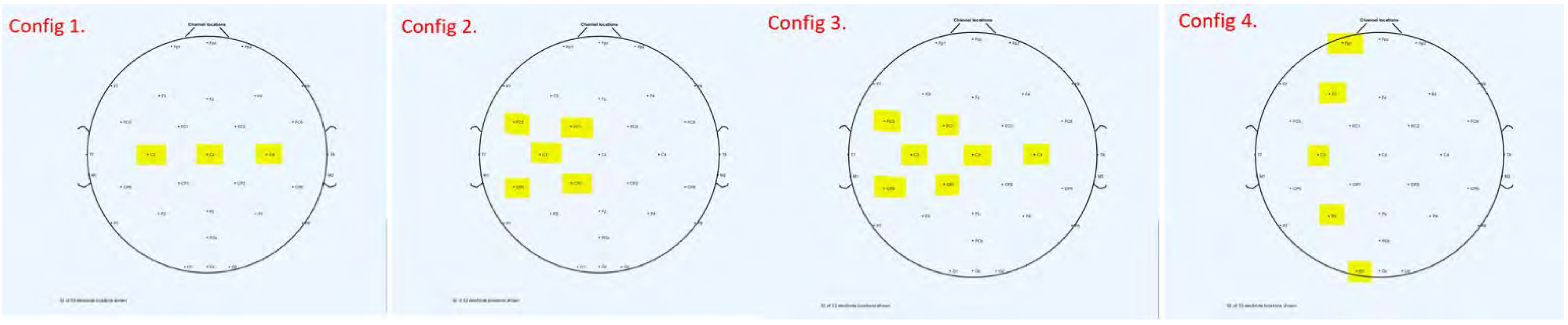

Figure 3. EEG electrode configurations (1-4)

Results

- Using a large pool of data recordings with varying electrode configurations (Fig. 3) we were able to train our MATLAB classifier via GPU processing.
- The selected channels resulted in various accuracy percentages with C3 showing an accuracy of 52.21% (Fig 4. C) and CP1 with an accuracy of 50.76% (Fig 4. D).

Channel	Accuracy	Average
Configuration 1		
C3	52.16 %	50.80 %
Cz	52.16 %	
C4	48.09 %	
Configuration 2		
FC5	52.16 %	51.09 %
FC1	52.16 %	
C3	52.16 %	
CP5	48.22 %	
CP1	50.76 %	
Configuration 3		
FC5	52.16 %	50.82 %
FC1	52.16 %	
CP5	48.22 %	
CP1	50.76 %	
C3	52.16 %	
Cz	48.09 %	
C4	52.16 %	
Configuration 4		
FP1	48.17 %	50.51 %
F3	52.16 %	
C3	52.16 %	
P3	52.16 %	
O1	47.88 %	

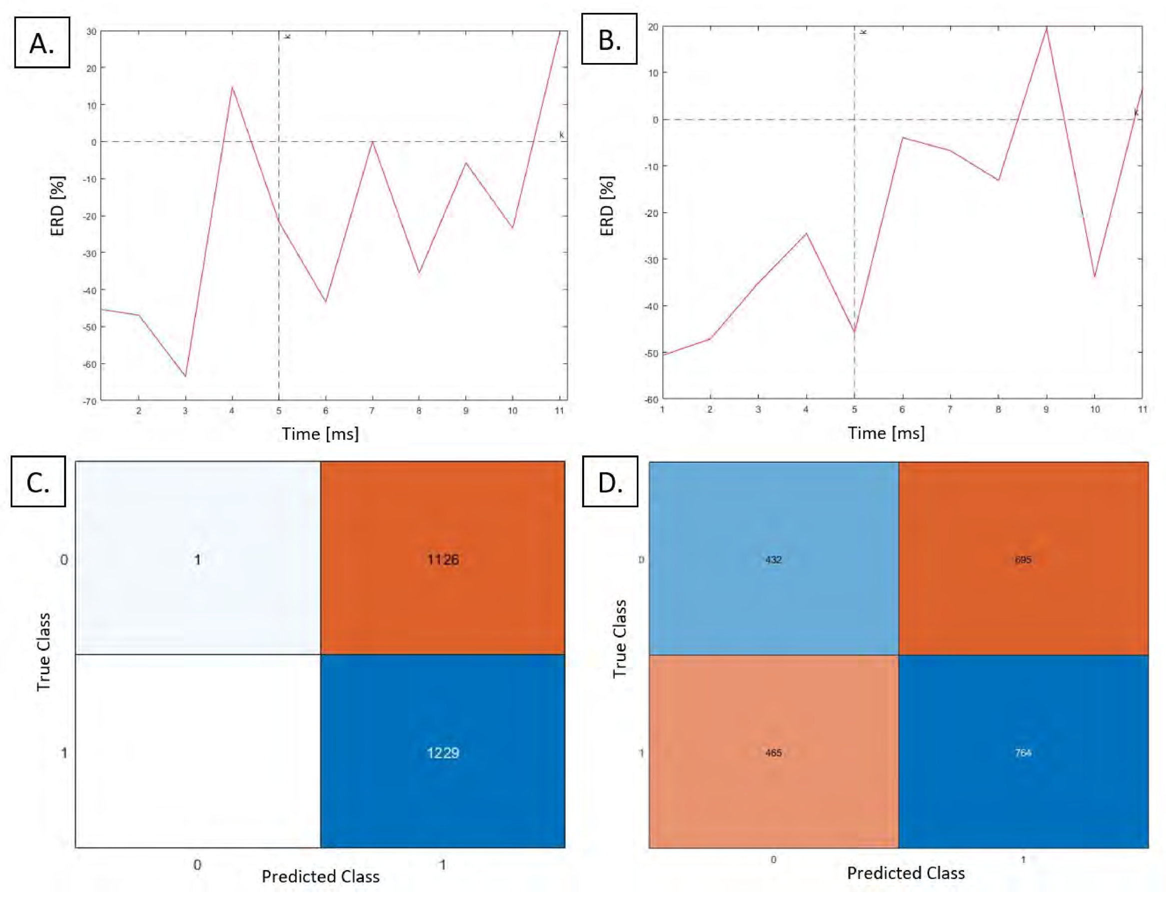

Figure 4. ERD plots (A, B) and Confusion matrices (C, D) of C3 SVM and CP1 SVM. Table shows the accuracy of each configuration.

Conclusion

- This BCI bypassed the muscles and nerve endings that would open and close a hand, and went straight from brain signals to action of the robotic hand in real time with low latency.
- This work can be improved in the future by a better fitting EEG cap, cleaner EEG data, and more relevant SVM training data.