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Abstract: BCI-based robot rehabilitation framework for stroke patients

Background & objective

Stroke is a leading cause of long-term motor disability among adults. Current rehabilitative interventions often do not help patients with severe motor impairment. Significant functional recovery after a year is rare despite novel interventional approaches for application in the chronic stage such as bilateral arm training or constraint-induced movement therapy [2].

Electrocorticographic (ECoG) based BCI [1] in combination with robot-assisted therapy can provide an alternative approach to neurorehabilitation, particularly for severely impaired stroke patients. Reinforcement of the patient own arm movements using a robot arm has been effective for moderately impaired stroke patients [3], but this is not a feasible option for severely affected stroke patients who are not capable of arm movement at all. In this scenario, we assume that brain signal based reinforcement of the patient's intent to move its own arm using a robot arm may have a positive effect in recovering his mobility, as it is a Hebbian rule-based therapy [4] in which stimulation of motor neurons using a robot arm is provided only when there is a patient's intent to move.

Methods

We have carried out a feasibility study developing a framework in which a BCI system is used to provide the basic control of a Barret WAM robot arm. ECoG activity evoked by the patient's intent to move a paretic arm in a pre-established rhythmic trajectory controls the robot arm, which in turn moves the paretic arm which is attached to the robot.

Our framework makes use of python-based real-time signal processing and optimization that builds on BCPy2000 [5]. Our methodology relies on the spectral content of the neurophysiological signals and it does not depend on off-line processing of pre-recorded signals, providing online feedback and ease of use.

Results

A framework in which a BCI system communicates in real-time with a robot arm has been developed. Basic control of a trajectory on a Barret WAM robot arm has been achieved by on-line processing and classification of neurophysiological signals.

After a short training period, the BCI system controls the movement of the robot arm in a continuous manner. A statistical learning algorithm is used to decide whether the robot arm continues or stops its movement over the pre-established rhythmic trajectory in an on-line fashion; every 100ms, the algorithm takes its decision based on the power spectral components of the last 500ms.

Our framework has been tested successfully with healthy subjects (employing EEG signals). Tests with stroke patients (with ECOG signals) are work in progress.

Discussion and conclusions

A novel framework that relies on the combination of BCI and robotics is proposed to significantly improve motor function of a paretic arm in stroke patients. Our study is a preliminary test bed that provides a basic system to control joints movement of a robot arm using a BCI system. More complex setups in which we aim to decode trajectories in 2-D and 3-D from the activity evoked by the patient's intent to move a paretic arm are to be followed in order to control a greater number of joints simultaneously. Subsequent controlled randomized clinical trials will be attempted.

References

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Keywords

brain-computer interface, robot arm, ECOG, stroke, neurorehabilitation.