2001 Progress on a Direct Brain Interface Based on Detection of ERPs in ECoG

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A direct brain interface is defined as a human−computer interface that accepts voluntary commands directly from the brain. This NIH bioengineering research partnership focuses on the development of a direct brain interface based on event detection in electrocorticogram (ECoG). Our goal is to enable people with disabilities to use such an interface to control assistive technology and improve their independence and quality of life.

The subjects for this research are patients in an epilepsy surgery program who have subdural macro electrodes placed as part of their treatment. Subjects are asked to perform a variety of actions while ECoG recordings are made. The ECoGs for a particular subject, action group, and session are defined as a single data set. To date, over 260 data sets containing over 10,000 electrode channel recordings (each mapped into 1 of 11 cortical areas) have been obtained from 39 subjects.

The basic method for the direct brain interface is based on the detection of event−related potentials (ERPs) in ECoG. First, averaged ECoG templates are developed using triggered averaging with the trigger based on EMG, switch activation, movement, or sound associated with the action. (Triggerless template development methods based on iterative cross−correlation using generic template models have been developed and are near implementation (Ferrise et al., 2000). Normalized cross−correlation is then performed between averaged ECoG templates from the first half of a channel and ECoG from the second half. Detections (defined when the cross−correlation values exceeded an experimentally determined threshold) that occur within 1 second before and 0.25 seconds after a trigger are considered "hits." The most accurate detections obtained so far have been 96% hits with 0% false positives (tongue protrusion action, from middle/inferior temporal gyri); 100% hits with 4% false positives (finger movement, from parietal lobe), and 100% hits with 7% false positives (tongue protrusion action, from postcentral gyrus) (Levine et al., 2000).

One focus for our current research is the improvement of detection methods and quantification of the effects of varying detection method parameters. Both time−based and frequency−based analyses are being explored.

The brain activity that forms an ERP in the time domain also appears as frequency−specific changes in the power spectrum of the ECoG signal. Short−term attenuation and intensification of power in particular frequency bands is termed event−related desynchronization (ERD) and event−related synchronization (ERS), respectively (Pfurtscheller and Lopes da Silva, 1999). We have found ERD/ERS effects in ECoG closely related to movement (Graimann et al., 2001). The ERD/ERS effects have been found on electrodes from which accurate ERP detection was possible using cross−correlation methods and also on adjacent electrodes. In the time domain, the occurrence of ERD and ERS are also evident in measures of the standard deviation of the ECoG templates that we have started to analyze.

These results demonstrate that the characteristics of the ECoG signal change over the duration of the averaged ERP template. We are examining the utility of these effects to select ECoG channels for direct brain interface operation using our current cross correlation based methods and as the basis of alternative detection methods.

Based on these findings, additional experiments are being performed to examine the effect of using different segments of the template on detection accuracy. Preliminary results of these experiments show that, as suspected, the accuracy of cross correlation –based detection using ERPs from movements depends on the ERP template segment used for cross correlation. To date, only pre−selected template segments have been tested. Incorporating findings from the ERD/ERS and standard deviation experiments should allow identification of the most significant time segments of the ERP template to use for detection. With this information, weighting or other modifications of the cross−correlation methods can be made for improved detection accuracy.

These avenues of investigation are expected to lead to more accurate and more dynamically responsive detection algorithms based on cross−correlation including a more efficient basis for triggerless template development. Additionally, they offer strong opportunities for new detection methods based on specific ERP signal characteristics.

These results provide good support for our direct brain interface approach based on cross−correlation of ERPs in ECoG by showing that ERPs related to movement can be detected with sufficient accuracy to form the basis of a functional direct brain interface. Movements related to different actions have been accurately detected, indicating the strong possibility that multiple control channels can be obtained.

Plans for work in the near future include on−line testing (with epilepsy patients) of direct brain interface performance which includes user feedback during the performance of functional actions. These experiments are expected to include pure imagery ’actions’ as well as actual movements. These experiments are designed to investigate the ability of human subjects to learn to modify characteristics of ERPs associated with cognitive activities for improved detection accuracy and subsequent assistive technology interface control. Preliminary experiments, while only at the very earliest stage, have clearly demonstrated some ability for such control.

References

G.G. Ferrise, J.E. Huggins, J.A. Fessler, S.P. Levine: "Triggerless Movement Specific Template Development for Use in Detecting Event Related Potentials." Chicago 2000, World Congress on Medical Physics and Biomedical Engineering, paper TU−FXH−131, 2000.

B. Graimann, J.E. Huggins, S.P. Levine, G. Pfurtscheller: "Visualization of significant ERD/ERS patterns in multichannel EEG and ECoG data", Clinical Neurophysiology, (in press), 2001.

S.P. Levine, J.E. Huggins, S.L. BeMent, R. K. Kushwaha, L.A. Schuh, M.M. Rohde, E.A. Passaro, D.A. Ross K.V. Elisevich, B.J. Smith: "A Direct Brain Interface Based on Event−Related Potentials." IEEE Transactions on Rehab. Eng., Vol. 8:2 p. 180−185, 2000.

G. Pfurtscheller, F.H. Lopes da Silva. "Event−related EEG/MEG synchronization and desynchronization: basic principles." Clin Neurophysiol 1999b;110:1842−1857.