2005 Progress on a Direct Brain Interface Based on Detection of ERPs in ECoG

J.E. Huggins, S.P. Levine, V. Solo, J.A. Fessler, D.M. Minecan, S.Y. Chun, R.C. Welsh, R.K. Kushwaha, and S.L. BeMent

University of Michigan, Ann Arbor, MI

Topic: Brain Computer/Machine Interface

The University of Michigan Direct Brain Interface project seeks to detect voluntarily produced event-related activity in human electrocorticogram (ECoG) during actual or imagined movements to operate assistive technologies. The project includes functional magnetic resonance imaging studies (Swaminathan et al., 2004), off-line data analysis, and feedback experiments.

Subjects from an epilepsy surgery program have subdural electrodes implanted for clinical purposes. They perform self-paced movements while electromyogram (EMG) onset is recorded to partially label rest and event classes. Our previous cross-correlation template matching (CCTM) method implicitly used a white noise model that ignores event-related power spectrum changes. A tractable model that includes spectral changes was made by assuming that every data point belongs to one of two classes (resting/event); each class has a zero mean Gaussian distribution with different and constant covariances, allowing simple hypothesis testing by the Neyman-Pearson lemma. For simplicity, we ignored the ERP component. An autoregressive (AR) model is used for each covariance.

The likelihood ratio simplifies (to within irrelevant constants) to the quadratic form:

$$\Lambda(x) = x' \, (K_0^{-1} - K_1^{-1}) \, x. \qquad (1)$$

For real-time implementation, the AR model reduces inversion of large covariance matrices to simple finite-impulse response (FIR) filters, with the running mean of the difference between the squared filter outputs used as the test statistic.

Applying this QUAD method to self-paced, partially labeled ECoG presents challenges. The time of EMG onset is labeled, but the time the subject decided to move is not. We label as $H1$ everything within a window size w and a center location c relative to EMG onset (values selected with maximum likelihood estimation). The remaining data, excluding a transition zone, is labeled as $H0$. A hysteresis threshold provides a data-dependent lockout and reduces multiple detections of a single event.

QUAD detection produced a hit percentage above 90% and a false positive percentage below 10% for 17 of 233 channels compared to only 1 for CCTM while reducing detection delay. With CCTM feedback, one subject used imagined tongue movements on line with 82% hits and 16.3% false positives. Replacing the CCTM method with the QUAD in feedback experiments should improve interface accuracy and response time.

Supported by NIH Bioengineering Research Partnership RO1 EB2093.

V. Swaminathan, J.E. Huggins, R.C. Welsh, D.N. Minecan, B. Graimann, Y. Jin, S.P. Levine. "fMRI studies to help plan implants for a direct brain interface," Neural Interfaces Workshop, 2004.