DETECTION OF EVENTS IN ELECTROCORTICOGRAM USING A QUADRATIC DETECTOR BASED ON A TWO COVARIANCE MODEL

S.Y. Chun, J.E. Huggins, J.A. Fessler, V. Solo, S.P. Levine
University of Michigan, Ann Arbor, MI

The University of Michigan Direct Brain Interface (UM-DBI) project seeks to detect voluntarily produced event-related activity in electrocorticogram (ECoG) during actual or imagined movements in humans as the basis for a Direct Brain Interface (DBI). Subjects are patients in an epilepsy surgery program who have subdural electrodes implanted for clinical purposes. The subjects perform around 50 self-paced repetitions of a movement around 5 seconds apart. Recording the onset of electromyogram (EMG) provides a partial labeling of rest and event classes. A detection method suitable for real-time operation is needed for use in an on-line test system to evaluate subjects' ability to learn direct brain interface operation.

Past work used a cross-correlation template matching (CCTM) method, implicitly based on a white noise model that ignores event-related spectral changes. To create a tractable model utilizing the event-related spectral changes, we make some assumptions about the ECoG. First, every data point belongs to either one class (resting state, H0) or the other (task/event state, H1). Second, each class has a zero mean Gaussian distribution with different and constant covariances, or each class is wide sense stationary. Thus, each class has only one constant covariance so we can use simple hypothesis testing by the Neyman-Pearson lemma. Third, we ignore the ERP component. For each covariance, we use an autoregressive model with zero mean, white Gaussian driving noise.

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

$$(x) = x' (K0-1 - K1-1)\, x, \qquad (1)$$

whose output is compared to a threshold for classification. This method is suited to real-time implementation because the AR model reduces the inversion of a large covariance matrix to simple finite impulse response (FIR) filters. The test statistic is the running mean of the difference between the squared filter outputs.

Application of this model to unprompted, partially labeled ECoG presents challenges. While the time of EMG onset is labeled, the time at which the intention to move was formed is not. We label as H1 data everything within a window size w and a center location c relative to EMG onset. Excluding a transition zone, the rest of the data is labeled as H0. Maximum likelihood estimation is used to select values for w and c. Thresholding the sequential detector output sometimes results in multiple detections of a single event so a hysteresis threshold is used to provide a data dependent lockout.

The QUAD method produces detection with a hit percentage above 90% and a false positive percentage below 10% for 17 of 233 interesting channels compared to only 1 channel for the CCTM method while simultaneously reducing the average delay.