Program#/Poster#: 728.1/NN28

Title: Optimizing spike sorting for brain computer interfaces with non-stationary waveforms

Location: San Diego Convention Center: Halls B-H

Presentation Start/End Time: Tuesday, Nov 06, 2007, 1:00 PM - 2:00 PM

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The highest performing brain computer interfaces (BCIs) rely on implantable electrode arrays. The inputs to their decoding algorithms are spike times extracted from single electrode broadband signals using spike sorting techniques. Existing techniques do not incorporate the decoding model and the performance of the BCI. In general, these techniques are based on unsupervised clustering algorithms applied to spike waveform shape data and/or interspike interval. The results of these algorithms can be ambiguous because the number of neurons recorded is unknown and the signal to noise ratio is often low. Further, existing spike sorting techniques assume stationary spike waveforms. Our recent empirical measurements indicate that these waveforms are not stable during free behavior: across 54 hours, significant spike waveform amplitude drift is observed (up to 30%), as are several step changes. Thus, we introduce two innovations. First, we use the results of a discrete communication BCI to guide the spike sorter. Expectation maximization (EM) fits a unit Gaussian mixture model (GMM) to waveform shapes transformed into a noise whitened principal components space. Individual Gaussians in the GMM are merged to form subsets in a hierarchical GMM (HGMM), with each subset representing a single neural unit. This merging process uses a set of greedy heuristics that try to maximize the performance of the BCI. We see improved performance in terms of both target accuracy and information transfer; preliminary results demonstrate up to a 8% reduction in the misclassification rate. Second, we extended our sorting techniques to allow for real-time iterative updates to maintain prosthetic performance when the underlying neural signals are unstable. The underlying GMM is updated using iterative EM, and heuristics are applied to update the HGMM. These methods may help maintain performance during continuous long-term prosthetic use, increasing clinical viability.

Disclosures: **V. Gilja** , None; **G. Santhanam**, None; **M.D. Linderman**, None; **A. Afshar**, None; **S.I. Ryu**, None; **T.H. Meng**, None; **M. Sahani**, None; **K.V. Shenoy**, None.

Support: NDSEG, Marco C2S2
NSF, MSTP, BioX
NIH-CRCNS, BWF,
CRPF, ONR
Sloan, Whitaker

[Authors]. [Abstract Title]. Program No. XXX.XX. 2007 Neuroscience Meeting Planner. San Diego, CA: Society for Neuroscience, 2007. Online.