evan_dastin-van_rijn@brown.edu

A novel method for DBS artifact removal: Period-based Artifact Reconstruction and Removal Method for DBS

Evan Dastin-van Rijn[1], Nicole Provenza[1,2], Matthew Harrison[1,3], Wayne K. Goodman[4], David A. Borton[1,3,5]

1. Brown University School of Engineering; 2. Charles Stark Draper Laboratory; 3. Carney Institute for Brain Science; 4. Menninger Department of Psychiatry and Behavioral Sciences, Baylor College of Medicine; 5. Department of Veterans Affairs, Providence Medical Center, Center for Neurorestoration and Neurotechnology

Overview

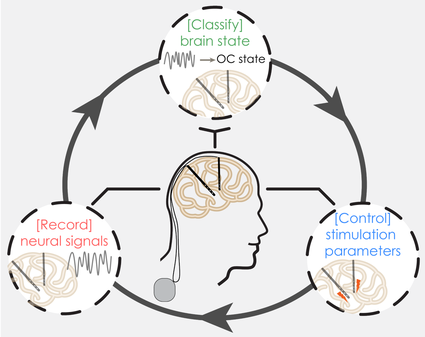
- High amplitude, high frequency DBS artifacts complicate biomarker detection necessary for the development of adaptive DBS therapy
- DBS artifacts are difficult to remove, especially in low sampling rate recordings where components of the artifact are aliased
- Existing methods rely on finding individual DBS pulses via thresholding which is ineffective for the low sampling rates and long artifacts characteristic of LFP recordings

Impact

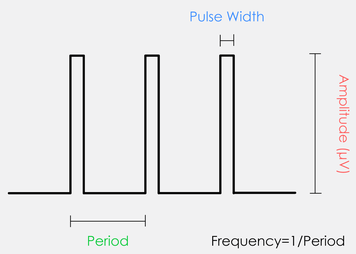
- Our novel method, Period-based Artifact Reconstruction and Removal Method (PARRM), improves on existing methodologies by accurately finding each instance of the artifact
- Our results demonstrate that PARRM is effective in removing high frequency DBS artifact from relatively low sample rate LFP recordings, without introducing contamination to the underlying neural signal.

Motivation

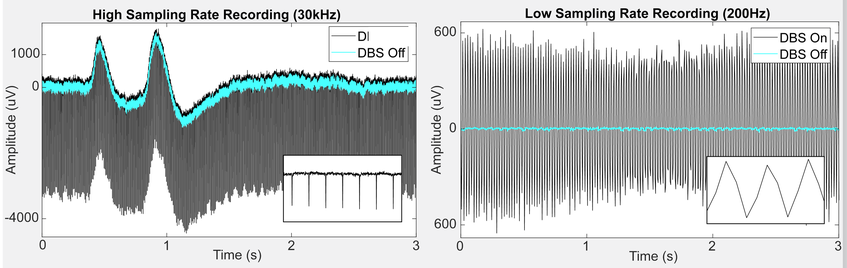
Adaptive DBS



DBS Signal



Concurrent DBS and Sensing

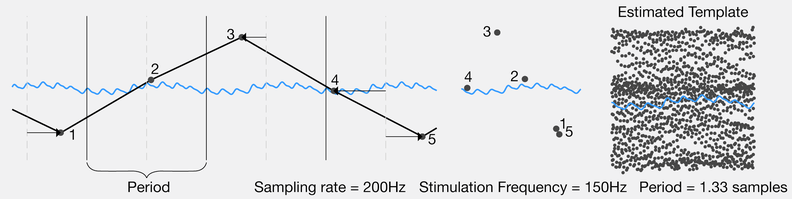


- Biomarker detection requires a hardware platform capable of concurrent sensing and stimulation
- The amplitude of DBS therapy is often orders of magnitude greater than underlying neural signals causing the signal of interest to be heavily contaminated by artifact
- In high resolution recordings, DBS artifact is typically removed using a simple low-pass filter
- However, in low sampling rate recordings, the artifact is aliased into biologically significant frequency bands requiring more complex approaches to artifact removal

Stimulation artifacts must be removed from LFP recordings in order to identify neural biomarkers of disease symptoms and side effects of DBS

Method

Initial Guess for the Artifact Period

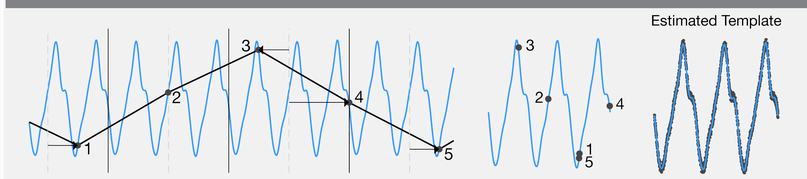


- The period is guessed by dividing the sampling rate by the stimulation frequency
- Slight differences in external factors make the sampling rate inexact
- The true period needs to be found in order to produce accurate templates

Finding the True Period

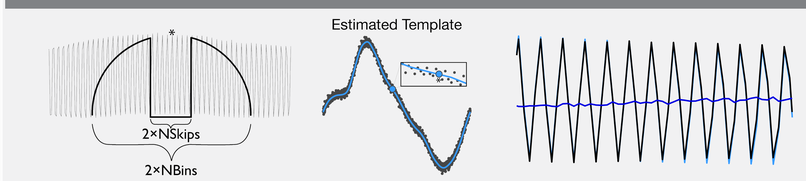
- A grid search is done around the initial guess to find the best period
- Periods are evaluated via linear regression with a sum of sinusoidal harmonics of the period
- The period which minimizes mean squared error with the raw data is chosen

Avoiding Distractors



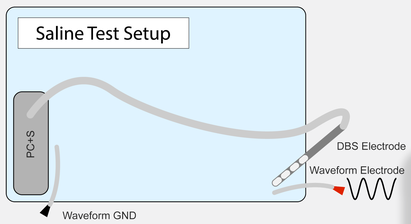
- We found that false periods can mimic harmonics of the artifact over short timespans
- To avoid such 'distractor' solutions, a penalty is included for regression coefficients for high frequency sinusoids which are less significant for the true solution

Removing Individualized Artifacts



- Once the optimal period is found, a region around each sample is used to construct a local template
- The value of the template corresponding to the phase of the sample can be subtracted in order to recover the artifact free recording

Validation

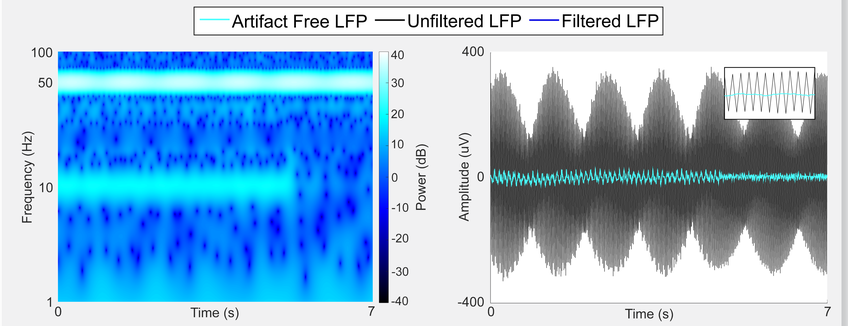


- Performance of PARRM was evaluated by recording signals (200Hz) in saline
- Stimulation (150Hz) was generated using a Medtronic Activa™ PC+S Neurostimulator and recorded along with known signals from a waveform generator

By recording stimulation and a known signal in tandem, the performance of PARRM can be evaluated by comparison to a ground truth

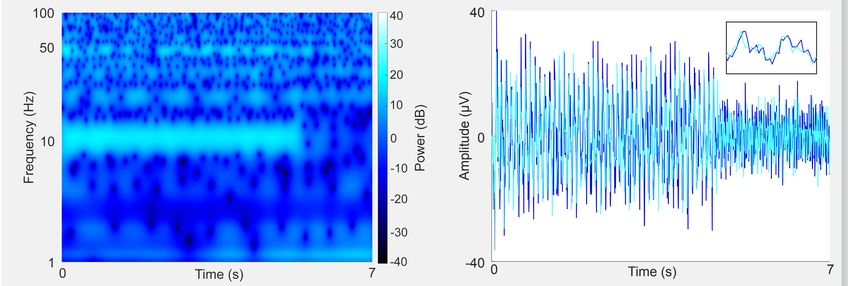
Results

Unfiltered Signal in Frequency and Time Domains



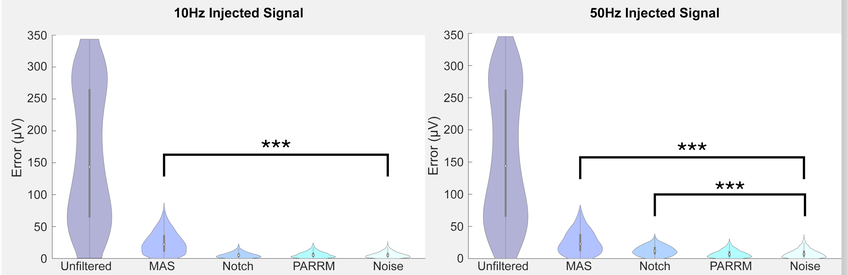
Injected 10Hz signal is visible in frequency domain but obscured by DBS artifact in time domain

Filtered Signal in Frequency and Time Domains



PARRM removes aliased artifact frequencies at 0 and 50Hz and recovers 10Hz signal in time domain

Comparison to Existing Methods



Unlike moving average subtraction (MAS) and notch filters, PARRM is able to return the error of a signal affected by artifact to the level of noise

Conclusions

- We developed a novel DBS artifact removal method termed PARRM
- Optimizing mean squared error between raw data and a Fourier series can be used to find the true artifact period
- PARRM is able to remove aliased artifact signals in the frequency domain and visually recover signals in the time domain
- PARRM returns the error to the noise level and significantly outperforms existing methods
- PARRM is able to recover injected signals at the frequencies affected by aliased artifact

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