Algorithm for the Correction of Motion Artifacts in fNIRS Data

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Objective

Identify and remove motion artifacts (MAs) from functional near-infrared spectroscopy (fNIRS) recordings using a kurtosis-based wavelet decomposition algorithm informed by synchronous inertial measurement unit (IMU) sensor data collected at every optode cluster.

Background

- Functional near-infrared spectroscopy (fNIRS) tracks hemoglobin changes to measure cortical activity but is highly susceptible to motion artifacts (MAs).
- Trends are shifting towards prolonged, natural setting recordings, requiring advanced MA correction to ensure the validity of signals for clinical applications.
- Our project addresses this limitation by combining motion sensors and signal processing techniques to improve data quality during natural movement.

Methods

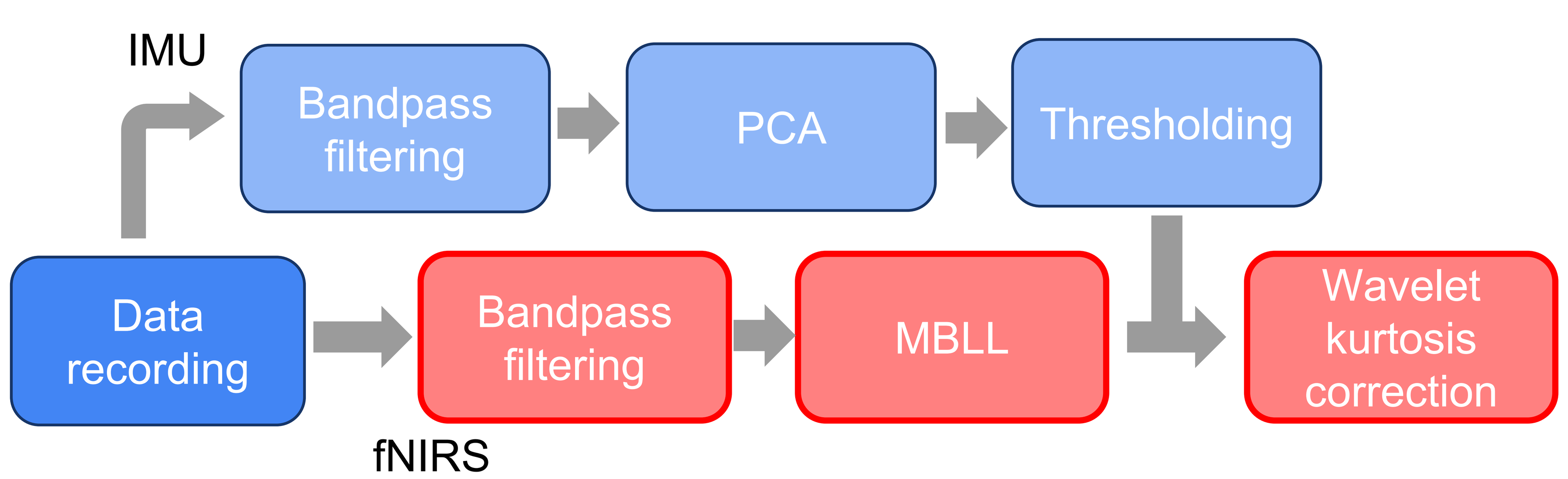

Figure 1. Overview of the fNIRS motion artifact correction workflow

- Accelerometer axes were combined using principal component analysis (PCA) and thresholds were calculated using standard deviation and interquartile range.
- Acceleration past the threshold triggered targeted correction. Wavelet decomposition levels were adjusted in response to local acceleration maxima
- Changes in hemoglobin concentrations were calculated using the modified Beer-Lambert law (MBLL).

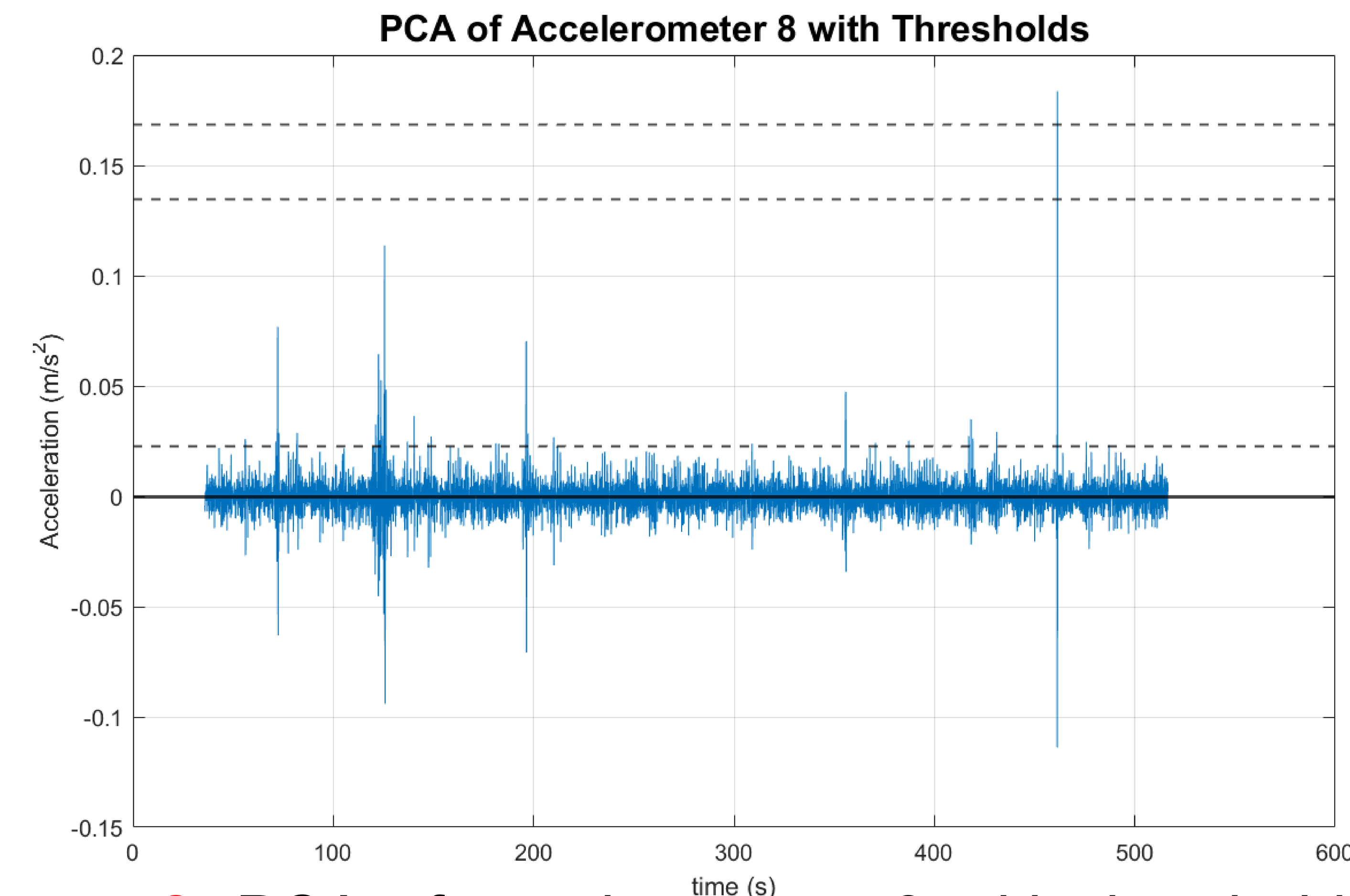

Figure 2. PCA of accelerometer 8 with thresholds. Wavelet decomposition level increases as local maxima surpass the successive thresholds.

Results

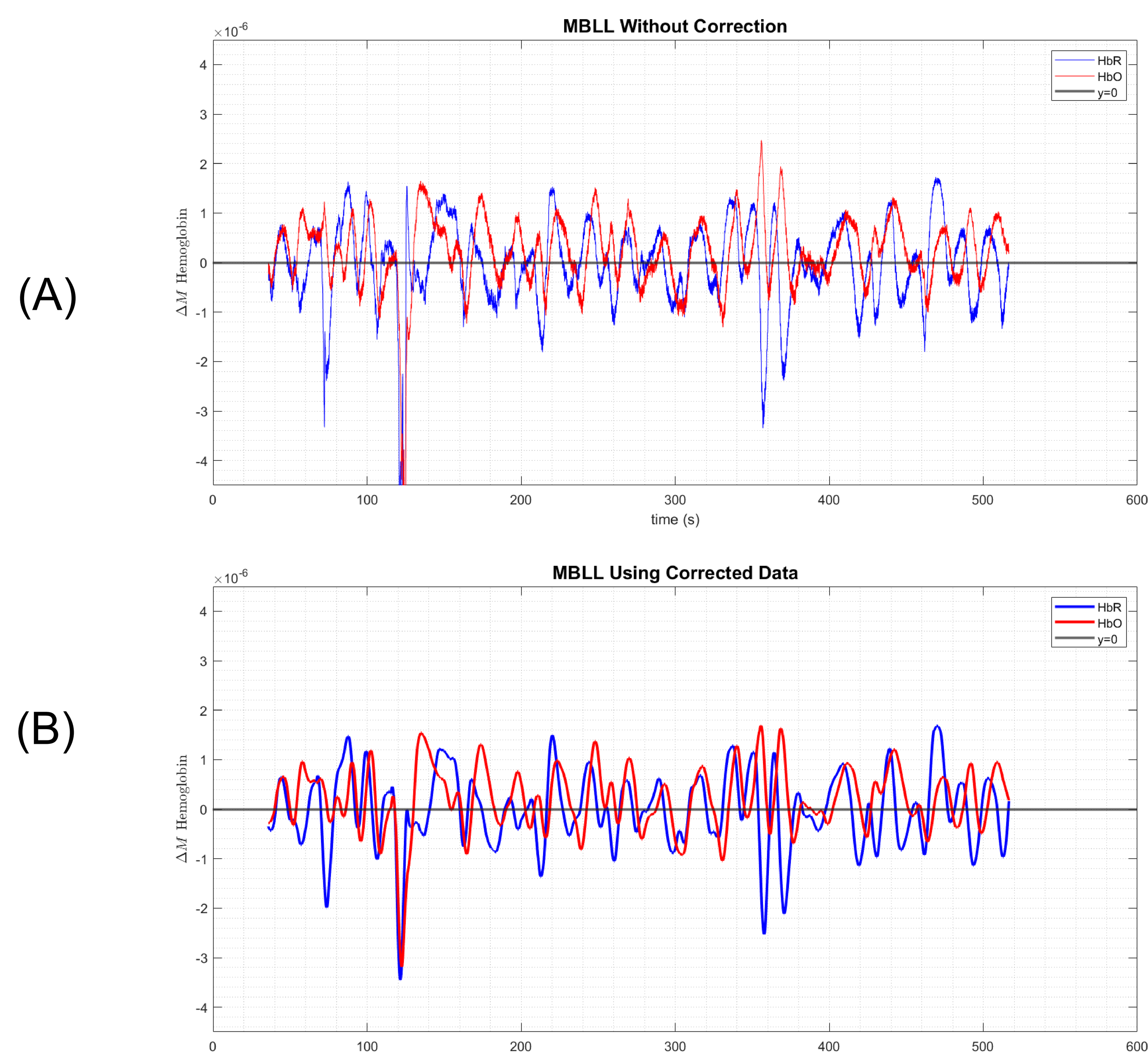

Figure 3. MBLL results using (A) NIRS data following a Butterworth bandpass filter and (B) wavelet kurtosis correction. The y-axis denotes relative concentration changes in moles/liter. Note, in 3A, the large negative spike near 120 seconds, and the increased amplitude of HbO near 350 seconds. Following correction, these distortions have drastically decreased.

	124.8 seconds	355.8 seconds
Uncorrected HbO	$-19.71\times10^{-6}\ \Delta M$	$2.47\times10^{-6}\ \Delta M$
Corrected HbO	$-1.97\times10^{-6}\Delta M$	$1.68\times10^{-6}\Delta M$
Percent change	90.00%	-31.98%

Table 1. Relative changes in hemoglobin concentration before and after motion artifact processing at the selected timepoints for the channels shown in figure 3.

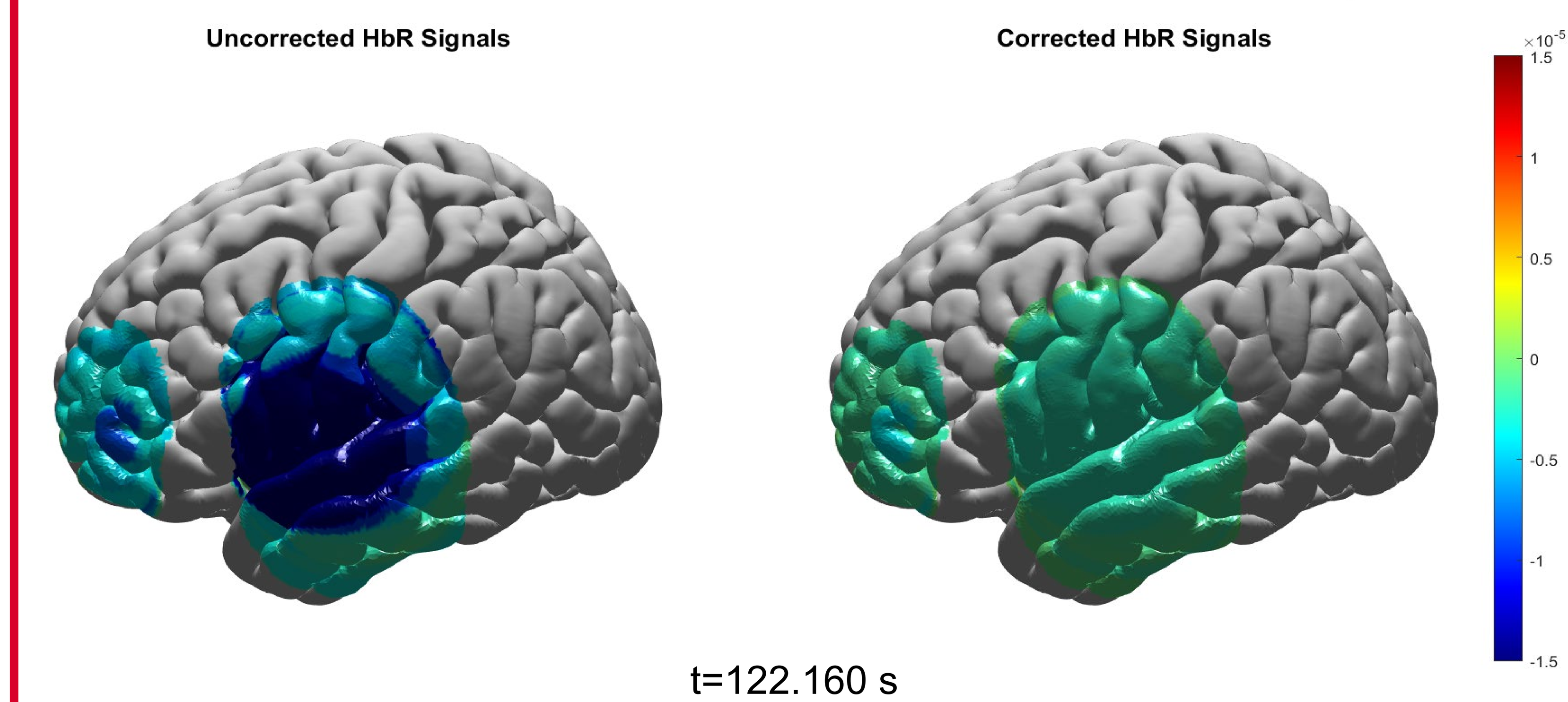

Figure 4. Mapping of uncorrected and corrected fNIRS signals onto a cortical surface generated in MATLAB. Take note that the dark blue readings correlated to a MA have been removed.

Conclusion

The proposed wavelet kurtosis-based algorithm can isolate and correct motion artifacts using adaptive IMU thresholds. This, paired with our GUI, allows researchers and clinicians to effectively monitor cortical activity in prolonged and natural setting studies without compromising signal integrity. Additionally, the algorithm has proven to be flexible during testing and may have applications in correcting artifacts in other modalities such as EKG and EEG.

Acknowledgements

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