NIRSplot: A Tool for Quality Assessment of fNIRS Scans

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Abstract: For a rapid and intuitive visual assessment of the quality of functional near infrared spectroscopy scans, we developed a software tool that automatically identifies entire optical channels or time intervals with compromised optical signals.

1. Introduction

Functional Near Infrared Spectroscopy (fNIRS) is a neuroimaging modality that measures hemodynamic changes associated to neuronal activity by means of neurovascular coupling. Advantages such as portability and rapid setup have contributed to the widespread use of fNIRS for brain monitoring in laboratory settings, as well as in real-world outdoor settings. Similarly to other wearable neuroimaging modalities (e.g., EEG), readings may be adversely affected by instrumental noise, movement artifacts and, specifically to fNIRS, poor contact between optodes and scalp, all of which contribute to a poor signal-to-noise ratio. However, standard measures for a quantitative evaluation of the quality of fNIRS data have yet to be established and scientifically agreed upon.

Existing approaches to the evaluation of data quality are primarily implemented in instrument-specific software and mostly rely on the detection of sudden changes in the baseline of the optical signal, i.e. prior to the engagement of the subject in any experimental activity. For instance, an excessive coefficient of variation of the optical signal, defined as the ratio of standard deviation to the mean, is often associate to poor quality due to subject movement or poor optode-scalp coupling and could also be used to discard a whole optical channel post-hoc. However, this measure is hardly applicable to the evaluation of task-related signals where the signal is expected to change. As a result, the identification of compromised optical channels or individual experimental trials is traditionally done by the user through a visual, qualitative analysis. Another situation that typically affects the efficient evaluation of signal quality and potentially its statistical analysis, is the one in which fNIRS scans include recording periods of no interest to the researchers, such as data collected during subject's preparation or instruction on how to perform an experimental task. In summary, there exists the need for computational tools for assessing the quality of the recorded fNIRS signals in an objective, timely and intuitive manner.

In this work, we present NIRSplot, a MATLAB-based tool for estimating the quality of an fNIRS signal based on physiology-related measures that are independent of the specific instrument and of the experimental paradigm being used. Specifically, this approach uses a combination of time-domain and frequency-domain measures of the strength of the systemic pulsation to evaluate both optode-scalp coupling and the presence of movement artifacts at all time points in a dataset. NIRSplot provides fNIRS investigators with a rapid and intuitive way to evaluate the data (at channel or trial level) towards improving the results of the subsequent statistical analysis.

2. Data quality measures

Knowingly, fNIRS signals are partially contaminated by systemic components such as cardiac pulsation, respiratory rate and vasomotion, among others [1]. On the other hand, a cardiac pulsation that is clearly visible in the fNIRS signal can be broadly seen as an indicator of a good optode-scalp coupling due to the prominent blood perfusion of the scalp. Notably, this signal feature is typically present throughout the entire fNIRS experiment, i.e. during both resting and active periods. In our previous work [2, 3], we introduced the Scalp Coupling Index (SCI) as a measure of the prominence of the photoplethysmographic cardiac signal, i.e. a waveform predominantly associated with the pulsatile volume of blood circulating in the scalp. From a raw fNIRS signal, we first extracted the cardiac pulsation by applying a band-pass filter with a cutoff frequency in the [0.5, 2.5] Hz range, corresponding to a heart rate between 30 and 150 beats per minute. A signal with good scalp-optode coupling is characterized by a strong pulsation of optical signals at both wavelengths, and we defined SCI as the normalized cross-correlation between the filtered versions of the signal at each wavelength. The SCI value ranges [0, 1], where 1 indicates an ideal synchrony between the cardiac pulsation at both wavelengths. Empirically, we established 0.8 as a reasonable threshold for identifying good scalp-optode coupling.

However, optodes movement during a scan typically bias SCI towards high values. To avoid this deceptive, albeit temporary indication of a good optical coupling, we used also the spectral power of the cross-correlated signal as an additional measure of data quality. Similarly to SCI, we empirically determined that a threshold value of 0.1 for the peak power is typically associated to a good quality signal; however, in contrast to SCI, signals containing movement artifacts yield values of peak power close to zero, thus they can be reliably identified by this spectral measure.

Overall, we considered an fNIRS signal to be sufficiently coupled to the scalp, hence possessing a necessary condition for being of good quality, if such signal yields high values of both SCI and peak power (as a logical AND) within a time window of *t* seconds. For our purposes, we will refer to the result of the last step as a *quality mask.*

3. NIRSplot tool

NIRSplot is a graphical output that summarizes the quality measures computed over the entire fNIRS scan, i.e. for all time windows and for all optical channels. NIRSplot consists of three graphical components: a File Loader (Fig. 1a), a Data Visualization window (Fig. 1b) and Channel Selection window (Fig. 1c). The loader window allows to select an fNIRS scan (i.e., currently, a .nirs file format) and, subsequently, it computes the quality measures (SCI, peak power, and quality mask views). The visualization window displays SCI and peak power values as greyscale images (optical channels vs. time axes) and, after thresholding, the boolean combination of both measures as a binary image. In addition, a fourth panel (Inspector view) plots the cardiac fNIRS signal of a selected optical channel or specific time window. In addition, NIRSplot performs an automatic identification of periods of interest (POI), depicted as the green bands in Figure 1 and defined as time windows around the onset of a stimulus. We identify POIs by computing the median time among the onsets plus half of the interquartile range value, and all brief gaps with a duration equal or less than the aforementioned value as part of the POI.

To perform an automatic selection of the channels to be considered for post-hoc analysis, the user can control the percentage of required high-quality windows within a given optical channel by adjusting such threshold in the channel selection window. The quantification of high-quality windows is made considering only those within the POIs. As a result, the list of channels achieving the quality requirement are marked in the fNIRS file for subsequent use with analysis tools as Homer or NIRS Brain AnalyzIR.

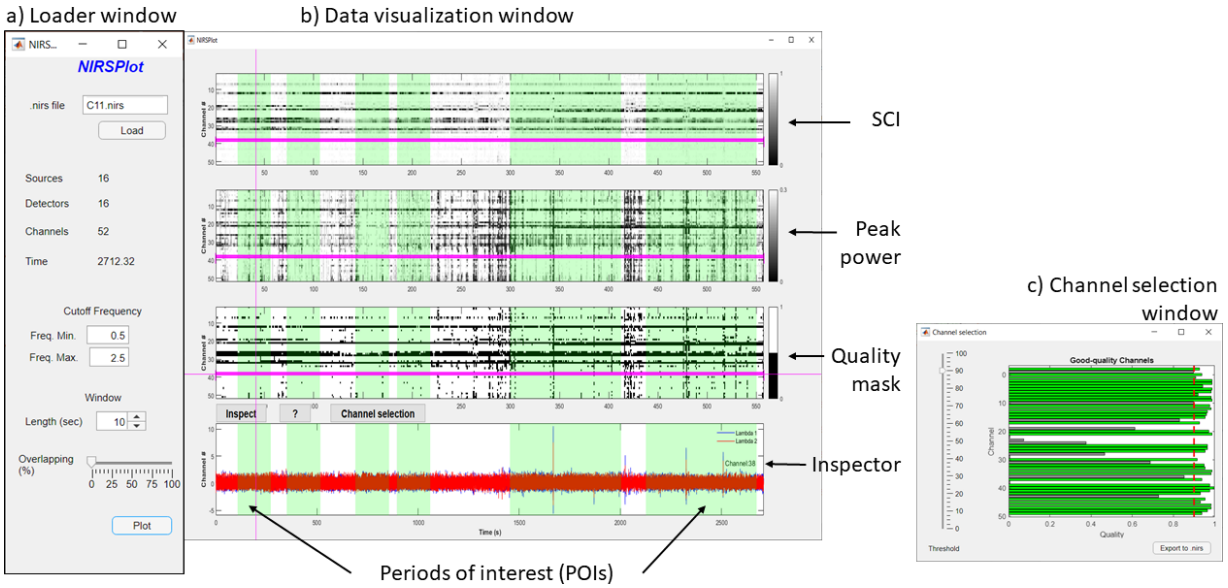

Figure 1. NIRSplot windows: File Loader (a), Data Visualization (b) and Channel Selection (C). Data Visualization window plots the ccalp coupling index (SCI), peak power, quality mask, and inspector views. Periods of interest (POIs) are shown as green bands.

4. References

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