Optimizing quantitative analysis of oxygenated and deoxygenated hemoglobin volumes in fNIRS time series measurements

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Introduction

fNIRS:
functional Near-Infrared Spectroscopy
→ Relatively nascent, non-invasive, portable technique
→ Measures brain activity by measuring changes in blood oxygenation
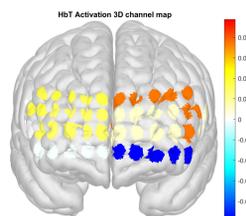→ Used to study cognitive, emotional, and motor functions

Figure 1. Representative brain activation channel map

Area under the curve (AUC)
of fNIRS time series data
→ Net change in blood flow volume
→ Provides insight into brain activity in specific regions

Research Aim
To develop an accurate method for calculating the AUCs of fNIRS time series graphs.

Hypothesis
The definite integrals of univariate spline interpolated approximations (DI) would yield more accurate AUC calculations than the trapezoidal rule approximations (TR) previously used in our laboratory.

Methods

1. Data gathered from 9 participants in a study examining brain activity across 3 tasks of varying difficulty (rest, least, most)
2. Data converted to SNIRF format with NIRSIT Scan
3. Data pre-processed & analyzed with block averaging in NIRSIT Quest
4. Time series data of the 9 participants' 8 Brodmann areas and 48 channels in the brain at the 3 difficulty levels were exported from NIRSIT Quest
5. AUCs of the oxygenated (HbO), deoxygenated (HbR), and total hemoglobin (HbT) graphs for each of the 1512 exported time series data files were calculated using a Python script utilizing the DI and TR methods.
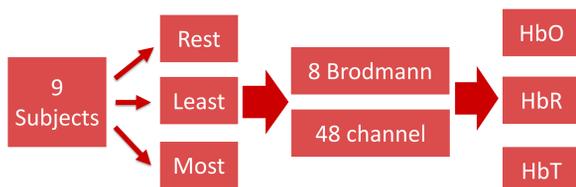

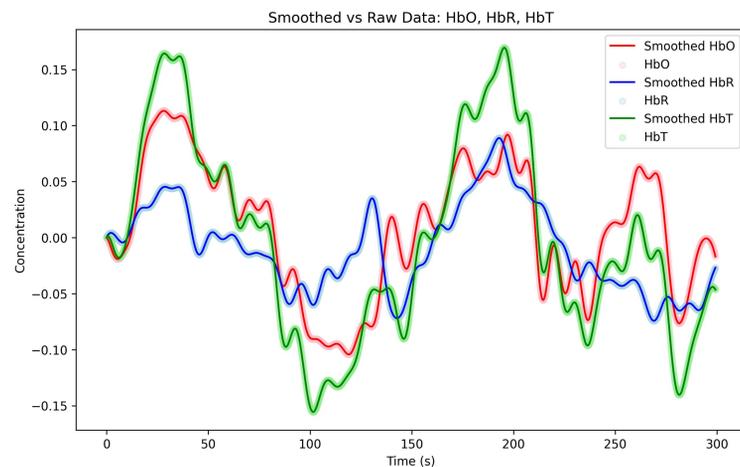Figure 2. Flowchart of the 4536 graphs analyzed

Results

Figure 3. Representative comparison of smoothed univariate spline approximation (opaque lines) to raw data points (translucent dots)
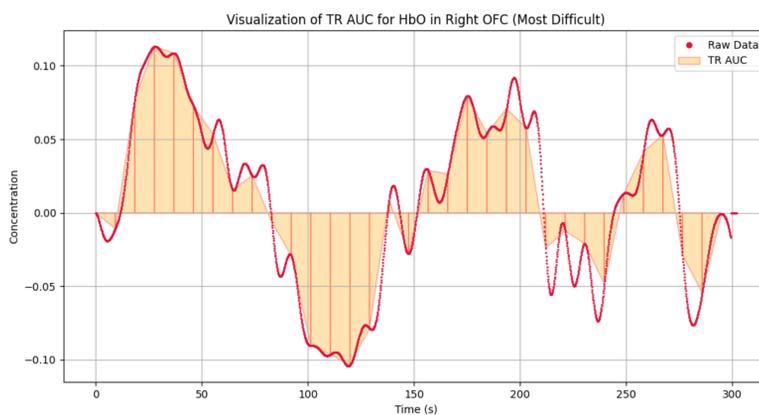

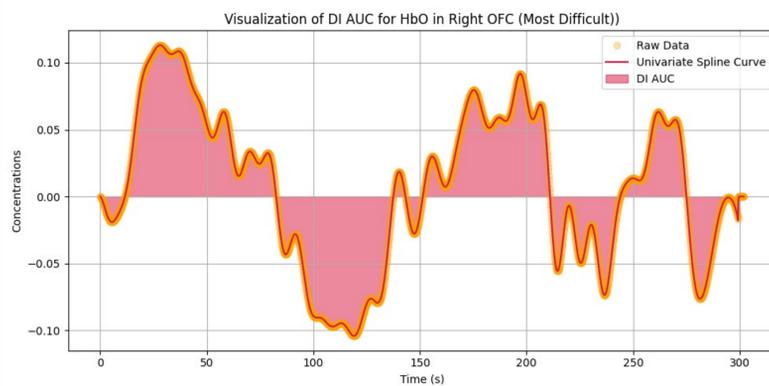Figure 4. Visualization of TR AUC approximation

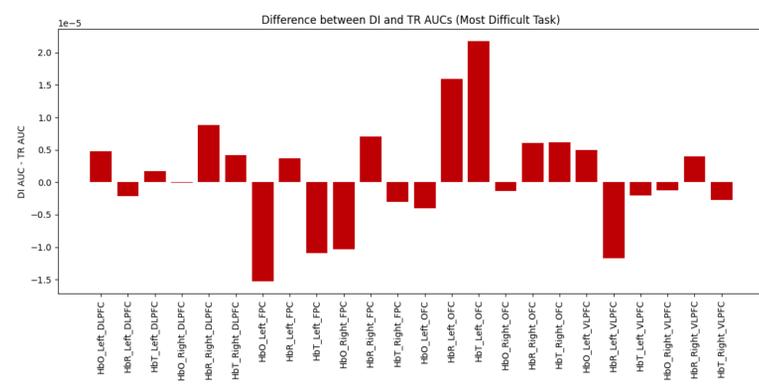Figure 5. Visualization of DI AUC approximation

Figure 6. Representative graph of the differences between DI and TR AUCs (y-axis scale: 1e-5)

AUCs	Median of differences
All data	1.0710000e-006
Brodmann time series	1.0720000e-006
Channel time series	1.0700000e-006

Table 1. Median of differences between TR and DI AUCs for all data, Brodmann data, and channel data

Discussion

• Statistical analysis via GraphPad Prism using a two-tailed Wilcoxon matched-pairs signed rank test of TR versus DI AUCs showed that there was a statistically significant difference, with a p-value less than 0.0001.
→ This indicates the two methods can yield results that lead to different interpretations or conclusions in a study.

• Further comparison of AUCs within either Brodmann or channel time series data also showed statistical significance between the TR and DI methods:
→ Brodmann time series data AUCs had a p-value of 0.006
→ Channel time series data AUCs had a p-value of 0.0003

• Given that the definite integral of a curve is mathematically more accurate than a trapezoidal rule approximation, these results suggest that using DI to determine the AUCs of fNIRS data yields more accurate results that are statistically significant from the TR method.

Conclusion

Our findings demonstrate that using definite integrals to determine AUCs in fNIRS time series data yields significantly different and more accurate calculations than trapezoidal rule approximations. Thus, implementing definite integral AUC analysis can enhance the precision and interpretability of fNIRS-based research.

References

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