Smart real-time processing and analysis of fNIRS neuroimages

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Project description:
Aim:
To develop and implement a real time processing and analysis pipeline for fNIRS neuroimages that intelligently optimises the extraction of endpoints AI challenges: Current real time pipelines for fNIRS are limited to naive prefixed filtering assuming a one-size-fits-all approach. Real time individual analysis is also virtually inexistent. Moreover, even off-line processing and analysis remains heavily expert driven with optimal automation remaining an open challenge. Certain applications however require both problems, neuroimage specific processing and analysis to be solved and be done in real time. We are not aware of any AI system yet capable of such feat.
Approaches:
1) Adaptation of a range of existing libraries to create an API ready for real time exploiting,
2) Using the building blocks developed in step 1, reformulation of the dynamic problem as a full model selection or evolutionary programming task,
3) Developing of a cost function to optimise the problem in step 2,
4) Verification and validation of the system against a human-expert ad-hoc solution.

Timeline (tentative):
1) End of Oct 2024: 2-pages plan agreed with student;
2) Dec 2024: Completion of Step 1 of the suggested methodology above and literature review on step 1, 2 and 3;
3) Jan-Feb 2025: Completion of step 2 and initial considerations for step 3;
4) Mar 2025: Completion of step 3;
5) Apr-Jul 2025: Model validation (Step 4);
6) June 2025: poster presentation;
7) End of Aug 2025: for final thesis submission.

Minimum viable thesis:
Plan B: Elimination of the analysis sub-pipeline focusing only on the processing.
Plan C: Implementation of a pipeline with only a decision tree to pick the among a range of processing options (this will still be better than the current prefixed choices).

Required background & skills:
Very strong mathematical and programming skills (preferably in Matlab but other languages are acceptable). A bit more specifically; substantial knowledge of signal/image processing, statistical hypothesis testing, intermediate knowledge of machine learning, and experiment design. Convenient but not mandatory from onset; Knowledge of fNIRS Neuroimage (data to be dealt with) and surgical neuroergonomics (domain of application).

Representative References:
Herrera-Vega, J., Trevino-Palacios, C. G., & Orihuela-Espina, F. (2017). Neuroimaging with functional near infrared spectroscopy: from formation to interpretation. Infrared Physics & Technology, 85, 225-237.
Escalante, H. J., Montes, M., & Sucar, L. E. (2009). Particle swarm model selection. Journal of Machine Learning Research, 10(2).
Ayaz, H., Baker, W. B., Blaney, G., Boas, D. A., Bortfeld, H., Brady, K., ... & Zhou, W. (2022). Optical imaging and spectroscopy for the study of the human brain: status report. Neurophotonics, 9(S2), S24001.

Pinti, P., Scholkmann, F., Hamilton, A., Burgess, P., & Tachtsidis, I. (2019). Current status and issues regarding pre-processing of fNIRS neuroimaging data: an investigation of diverse signal filtering methods within a general linear model framework. Frontiers in human neuroscience, 12, 505.
Yücel, M. A., Lühmann, A. V., Scholkmann, F., Gervain, J., Dan, I., Ayaz, H., ... & Wolf, M. (2021). Best practices for fNIRS publications. Neurophotonics, 8(1), 012101-012101.