Automatic recognition of cognitive workload from fNIRS neuroimages

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Project description:
Cognitive workload refers to the amount of brain resources being used to tackle some task. High workload is associated to higher error risks or decays in performance and hence the importance of automatically detecting it in the in surgeons as they operate.
Aim:
To develop and implement a feature extractor and classifier capable of identifying episodes of high cognitive workload.
AI Challenge:
Cognitive workload is a loosely defined term which is on its own a debated construct. Its relation to observable behaviour is non-monothonic, and current surrogates are far from successful. Lacking a strict universal definition, in the current state of the art, this research is looking for a moving target. In this project, we seek to explore a potential set of features on the fNIRS neuroimages that can contribute to decode and explain the cognitive workload, and use such features to build a naive alarm system in the field of surgical neuroergonomics.
Approaches: Departing from a surgical neuroergonomics dataset of fNIRS neuroimages;
1) Wrangle, clean and curate the dataset,
2) with the use of concomitant estimators of cognitive workload e.g. SURG-TLX, explore the data for patterns that can either provide a predictive or explanatory edge for subsequent classification, and
3) using modern ANN, develop and implement and architecture that exploit these features and can classify episodes of high cognitive workload online in a simulated streaming of the data, .e.g in near real-time as if data was being collected.
Finally, 4) the model will be validated against a human-expert labelled episodes.

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: We perceive the development of the classifier (step 3) as a somewhat easier task than the feature engineering (step 2). It is possible that such feature engineering ends up consuming most of the project timing. If this was to be the case, we shall focus on a more thorough analysis of promisory features i.e., factor analysis, and sacrifice the development of the classifier.

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:

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