Multi-class task classification using functional near-infrared spectroscopy

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Abstract: This paper reports on a study conducted with nine human subjects on six different cognitive tasks. The study collected brain activity data from the participants using a 52-channel functional Near-Infrared Spectroscopy (fNIRS) sensor. The resulting dataset was labeled with the task type administered. After analyzing the across subject dataset using a multi-class decision tree classifier, the results show a promising F1 score of 0.94. The most predictive features for the classification are reported to guide future research into this area. The implications of this work include a generalizable task classifier based on brain activity data.

Introduction: Task classification is fundamental in human-computer interaction because it can be used to build better user models and for computers to adapt to the nature of the user's tasks. By understanding the nature of the user's task, the interface can change its presentation so that task usability is improved. Thus, task classification can be a first step towards better Brain-Computer Interfaces.

Methods: The brain activity data was collected by a Hitachi ETG-4000 fNIRS device which can capture 52 channels of Oxygenated hemoglobin (HbO) and Deoxygenated hemoglobin (HbR) concentration data. The optodes were arranged in a 3 X 11 formation and placed over the participants' forehead area. The fNIRS sensor captured the brain activity in the prefrontal cortex at 10 Hz frequency. A total of nine subjects took part in the experiment; all of them were college-age students from a university in the northeast united states. The participants were presented six cognitive tasks and their brain activity recorded. The brain activity data were first preprocessed into statistical features, mean, minimum, maximum, standard deviation. These features were calculated on a per-trial basis. Along with the labels, these features constitute the complete dataset. The dataset contained 2996 trials representing the six cognitive tasks. The dataset was analyzed in leave one subject out cross validation method.

Results: An F1 score of 0.94 was achieved for the six-class classification, which is very encouraging compared to the state-of-the-art.
Minimum HbO and minimum HbR statistical features have more substantial predictive power than the other features. This could be due to the minimum values being connected to the variation of brain activity influenced by the different tasks. The mean of HbO and HbR was also a strong indicator of task classification. Interestingly, the most predictive features showed an even spread between HbO and HbR. Showing that they both show inter task variation. The predictive regions that were most active include the orbitofrontal cortex and dorsolateral prefrontal cortex. Future research into task classification could further focus on these areas using fNIRS devices with higher resolution.

Conclusion: This study shows promise for a generalizable across-subject multi-task classifier from fNIRS data. Such a system would provide the ability to identify the "type" of content a user interacts with on a computer. Thus, helping to build better user models. While this work shows promise for the generalizability of this approach, it would be important to conduct further experiments in a larger group of users with real-world tasks that contain combinations of cognitive processing in varying amounts.

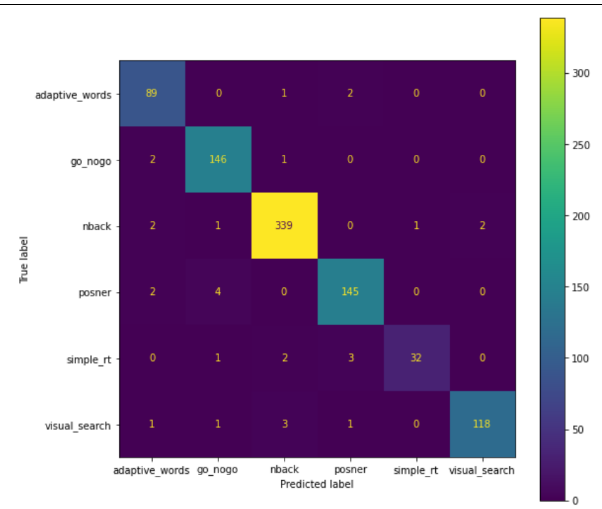

Figure 1: Confusion matrix for task classification for leave subject 1 out validation