Applying Machine Learning to Link Brain Activity and Social Behavior

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1 Research Motivation

Machine learning techniques have become very useful in the field of social interaction and neuroscience, especially in identifying the link between the brain and behavior. In particular, the analysis of temporal dependencies between behavior and brain activity is an important step towards the investigation of the brain bases of natural social behaviors [1]. The purpose of this thesis is to conduct original works involving explainable artificial intelligence in order to tackle the following questions:

- Investigating social mechanisms involved in Human-Human Interaction (HHI).

- Understanding the relationship between brain activity and behavior.

- Try to answer the question: what happens in the brain when we speak?

2 Problem Statement

The challenge is to understand relationships between complex behaviors and activity in the social brain during unconstrained interactions. It poses one major difficulty in terms of the explanatory variables to use and their ability to explain and predict the target variables. The multi-modality of the input signals raises also a challenge in terms of synchronisation and data structuring taking into account the time resolution of the target variables (the measured brain activity). For example, when using Functional magnetic resonance imaging (fMRI), the frequency of the recorded images is generally too small compared to the frequency of the behavioral signals (e.g., audio and video) [2]. The methodological challenge is how to represent the dynamic function between behavior and brain activity, and how to apply efficiently deep networks considering the multi-modality and the temporal aspect of the data.

Many works have analyzed dependencies between behavior and specific functional brain areas. However, one or few modalities are included to describe the behavior [3, 4]. In addition, the methods used are generally based on correlation analysis or multiple regression, while advanced deep learning models could be used.

3 Research Scope

The aim of this thesis is to propose and develop and machine learning system that helps to understand the links between behavior brain activity of different Regions of Interest (ROIs). The topics of this PhD project include signal processing, feature extraction, deep learning and multi-modal prediction. The expected methodology is based on three steps:

- Building machine learning models to predict the brain activity based on high-level features extracted from raw conversational signals (linguistic features, audio features (MFCC), emotions, facial features, ...).

- Combining feature selection methods and prediction models to find causal relationships between behavioral and neuro-physiological time-series.

- Improving the BrainPredict tool ([5]) for brain activity prediction and visualization in real time during a bidirectional conversation.

4 Admission Criteria

The PhD position is proposed by the International Center of Artificial Intelligence of Morocco, of the Mohammed VI Polytechnic University. Applicants with excellent cursus must be holders of a Master's, an engineering or an equivalent recognized degree in Computer Science or Applied Mathematics. In addition, they should have skills in Programming (Python and C++) and good communication skills in English. Particular attention will be given to the suitability of this research project with the applicant's background.

References

[1] Talmo D Pereira, Joshua W Shaevitz, and Mala Murthy. Quantifying behavior to understand the brain. *Nature neuroscience*, 23(12):1537–1549, 2020.

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[3] Alexander G. Huth, Wendy A. de Heer, Thomas L. Griffiths, Frédéric E. Theunissen, and Jack L. Gallant. Natural speech reveals the semantic maps that tile human cerebral cortex. *Nature*, 532(7600):453–458, April 2016.

[4] Hsuan-Yu Chen, Yu-Hsien Liao, Heng-Tai Jan, Li-Wei Kuo, and Chi-Chun Lee. A Gaussian mixture regression approach toward modeling the affective dynamics between acoustically-derived vocal arousal score (vc-as) and internal brain fMRI bold signal response. In *2016 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, pages 5775–5779. IEEE, 2016.

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