EEG2fMRI: Cross-Modal Synthesis for Functional Neuroimaging

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1   Introduction

Neural activity is central to investigating cognition. It has been employed to study the neural correlates of numerous cognitive functions, such as perception, attention, and memory. It has also been employed for characterizing, diagnosing, and ameliorating a wide range of neurological conditions.

The increased relevance of neural activity in cognitive science prompted the development of a large number of functional neuroimaging techniques. These techniques can be effectively described in terms of spatial resolution, temporal resolution (sampling rate), and portability. The most widely used functional neuroimaging techniques are EEG and fMRI. EEG scanners consist of arrays of electrodes placed directly on the user's scalp. They are extremely portable and have high temporal resolution, with modern variants routinely performing thousands of readings every second. However, such scanners can only detect neural activity after first being filtered by the skull, leading to a major decrease in spatial resolution. Conversely, fMRI is based on electromagnetic waves which easily penetrate the skull. Therefore, it has high spatial resolution, but is lacking in most other aspects. It is hundreds of times more expensive than EEG, it is thousands of times slower than EEG, and it is virtually unmovable by its user.

Given the lack of techniques which individually exhibit high overall performance, there have been numerous attempts to integrate their complementary qualities by using multiple techniques simultaneously. EEG-informed fMRI, fMRI-informed EEG, and neurogenerative modelling are all methods of integrating data from simultaneous EEG and fMRI recordings. However, these methods require two techniques and are limited to niched applications.

Besides multi-modal functional neuroimaging, investigators have also proposed uni-modal synthesis as a method of augmenting neuroimaging techniques. This task consists of conditionally synthetizing novel data based on previous data collected through the same modality. This method has been found to increase performance in downstream classifiers based on fMRI data.

In addition to uni-modal synthesis, investigators have also proposed cross-modal synthesis for augmenting neuroimaging techniques. This task consists of reconstructing data collected through a target modality based on data collected through a distinct source modality, by exploiting the inherent relation between them. In a setting where both source and target modalities are available, this task might have limited utility. However, the value of cross-modal synthesis comes from settings where only one modality is available. In such settings, data collected through an unavailable modality can be approximated. Unfortunately, this approach has largely been used for augmenting structural neuroimaging, with limited analogous efforts for functional neuroimaging.

Despite the major demand for high-performance functional neuroimaging and the success of cross-modal synthesis for structural neuroimaging, limited attention has been given to cross-modal synthesis for functional neuroimaging. The purpose of the current work is to formalize and explore the feasibility of EEG-fMRI synthesis. This comes as a natural extension of the growing collection of functional neuroimaging augmentation methods.

The task of modelling the relation between two modalities can be addressed through different approaches.

The suitability of EEG-fMRI as a candidate pair for cross-modal image synthesis is supported by the established practices of multi-modal neuroimaging using EEG-fMRI. These practices are the result of biophysical compatibility and the presence of complementary qualities.

Not only are EEG and fMRI compatible and complementary, but their results are also strongly correlated. The correlation occurs because both techniques are designed to detect neural activity.

Model architecture: convolutional, residual

Evaluation: mse, psnr + mae, statistical test