Decoding the Brain: Extracting Visual Information from fMRI Scans

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1. Introduction

When we first started our research we focused on the decryption of neural activity in order to reconstruct spoken word to synthesized speech by decrypting EEG data with a deep learning model based on the paper "An open-access EEG dataset for speech decoding: Exploring the role of articulation and coarticulation" [2]. We hoped that this would have applications in patients with speaking disabilities. However, seeing that the coursework has been in computer vision, we pivoted our vision to focus more on the decryption of fMRI scans in order to replicate a patients vision at the time of the scan. Seeing that it was published in 2024, the DREAM paper [3] by Weihao Xia and colleagues will serve as a guideline for our work in the construction of our own deep learning model for the decryption of human vision from neuronal activity.

DREAM (Visual Decoding from REversing HumAn Visual SysteM) is an innovative approach designed to reconstruct images from fMRI data by mimicking and reversing the visual processing pathways of the human brain. The system comprises two main components: Reverse-VAC, which recovers semantic information from fMRI signals, and R-PKM, which predicts color and depth. This biologically interpretable method surpasses existing techniques in reproducing images that maintain appearance, structure, and semantics of the originally visualized image.

We also plan on leveraging techniques from the paper "Generic decoding of seen and imagined objects using hierarchical visual features" [1] which introduces a novel approach to object recognition in both human and machine vision, leveraging deep convolutional neural networks (CNN) to decode seen and imagined objects from fMRI patterns based on hierarchical visual features. Unlike traditional classification-based decoding, which is constrained by training examples, this method allows for the identification of arbitrary object categories by predicting visual features across different brain areas. The research utilized visual features from CNN, HMAX, GIST, and SIFT + BoF models which we plan on researching and implementing partially.

2. Milestones

1. Understand the biological and computational foundations behind DREAM, reviewing the literature on similar topics.
2. Acquire and preprocess the Natural Scenes Dataset (NSD) or a comparable fMRI dataset for training and testing the DREAM models.
3. Develop and tra in models similar to Reverse-VAC and R-PKM to decode fMRI data, utilizing advanced learning techniques, with deliverables including trained models and performance metrics.
4. Implement a decoding algorithm to reconstruct images from fMRI data, merging outputs from Reverse-VAC and R-PKM, with the deliverable being a functional algorithm and a comparison interface.
5. Test our model against a set of novel data, tuning the steps above to optimize performance and finalize the model.

We plan on dividing tasks based on the individuals skillsets. Andrea and Andrew will be focusing on code and Camille will be focusing on data analytics and normalization. We will meet weekly in order to assign tasks and check in on progress, using a team-organization software to ensure accountability and pacing of the project.

References

[1] Tomoyasu Horikawa and Yukiyasu Kamitani. Generic decoding of seen and imagined objects using hierarchical visual features. *Nature communications*, 8(1):15037, 2017. 1

[2] João Pedro Carvalho Moreira, Vinícius Rezende Carvalho, Eduardo Mazoni Andrade Marçal Mendes, Ariah Fallah, Terrence J Sejnowski, Claudia Lainscsek, and Lindy Comstock. An open-access eeg dataset for speech decoding: Exploring the role of articulation and coarticulation. *bioRxiv*, pages 2022–11, 2022. 1

[3] Weihao Xia, Raoul de Charette, Cengiz Oztireli, and Jing-Hao Xue. Dream: Visual decoding from reversing human visual system. In *Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision*, pages 8226–8235, 2024. 1