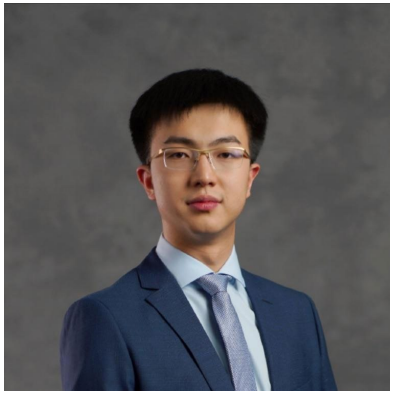
“Mind Reading”: Decode Visual Images from Brain Activities

Data Science Live – STAT 571/701

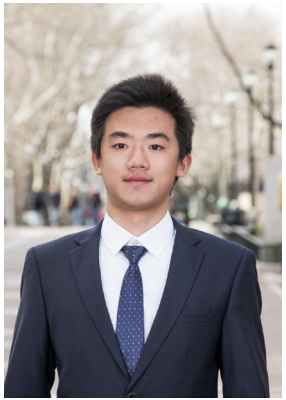
Shaolong Wu, Yuzhou Lin, Lingqi Zhang

Members



Shaolong Wu

- **Hometown:** Nanjing, China
- **School:** Wharton, Engineering
- **Program:** BS in Economics, MSE in Electrical Engineering
- **Research Interests:** Econometrics



Yuzhou Lin

- **Hometown:** Sichuan, China
- **School:** College, Engineering
- **Program:** BA in Mathematics, MSE in Data Science
- **Research Interests:**
- Biostatistics, Data Science

Lingqi Zhang

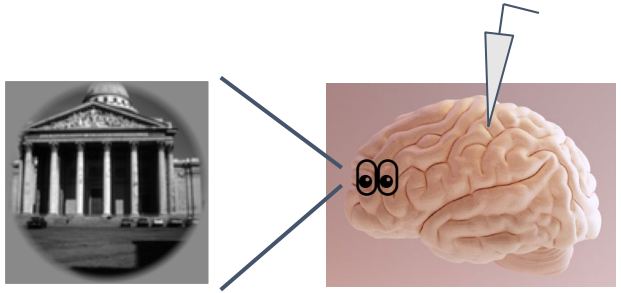
- **Hometown:** Zhejiang, China
- **School:** Arts and Sciences
- **Program:** PhD in Psychology
- **Research Interests:** Visual System, Computational Neuroscience

Introduction

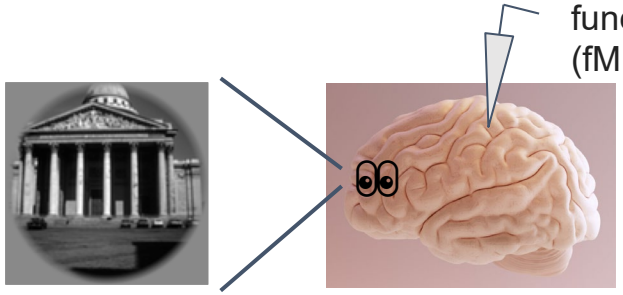
- Understanding the brain is one of the most important and challenging problem

∼ 100 billion neurons
∼ trillions of connections (synapses)

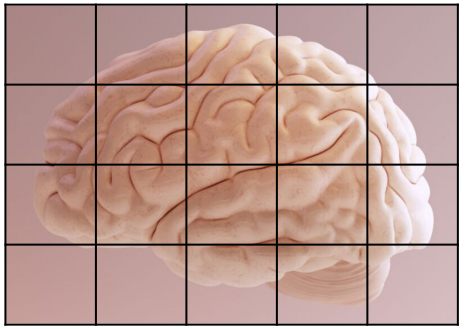
- External stimulus - Brain activities
- Visual cortex

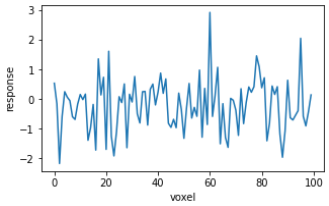


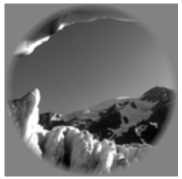
Introduction

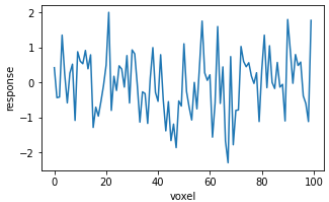


functional magnetic resonance imaging (fMRI)

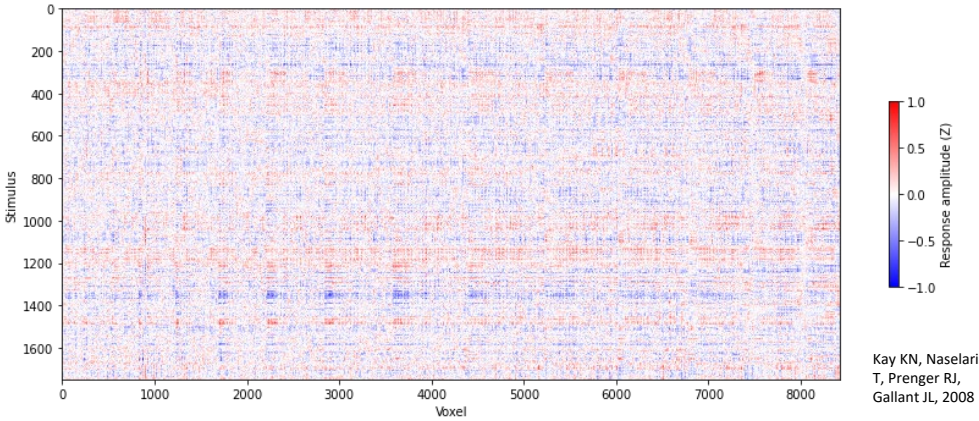








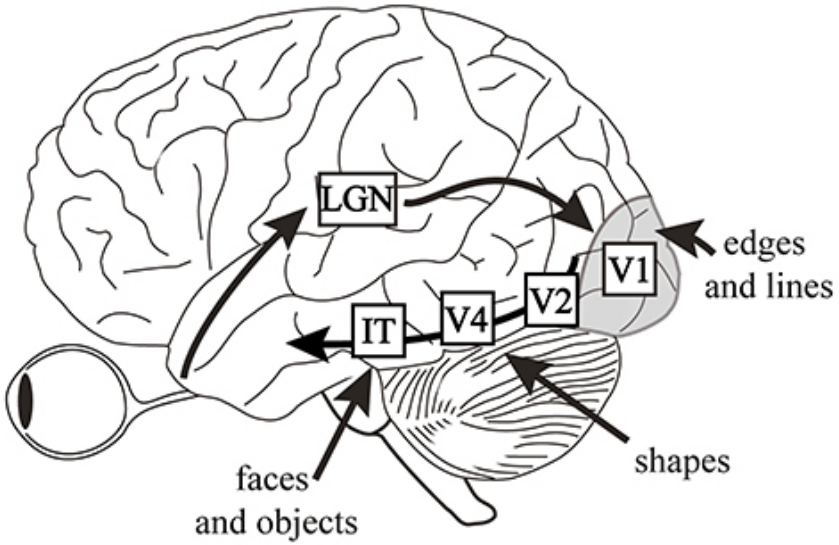
> 8000 voxel,
> 1750 images for training, 100 images for testing



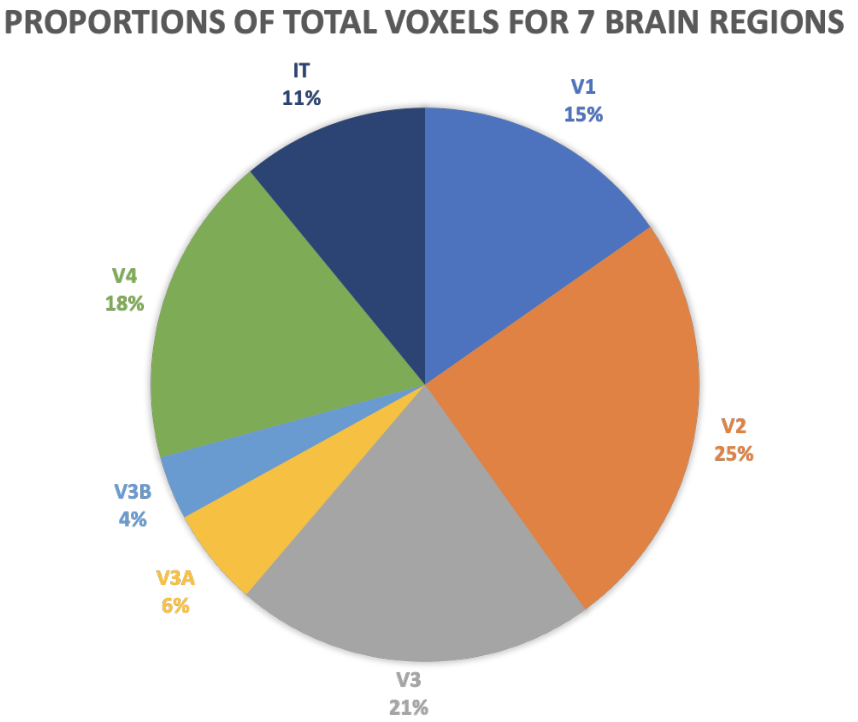
Kay KN, Naselaris T, Prenger RJ, Gallant JL, 2008

Introduction

Visual system is ***Hierarchical***

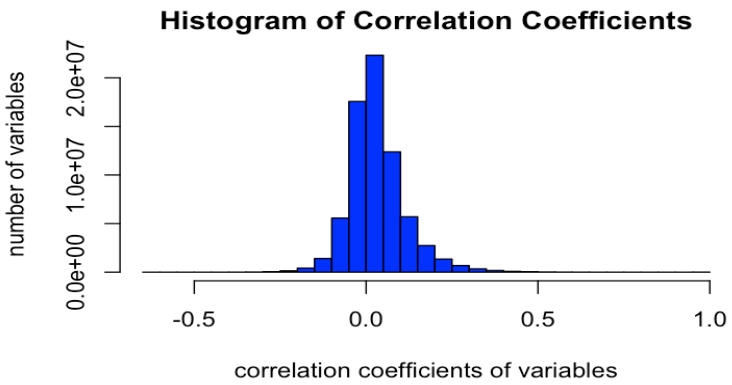


Herzog & Clarke, 2014

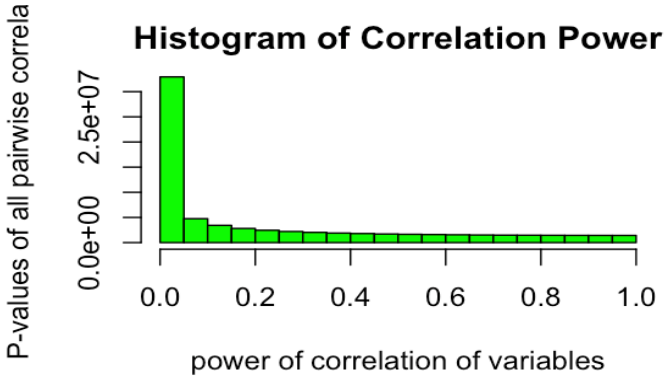


Before Decoding

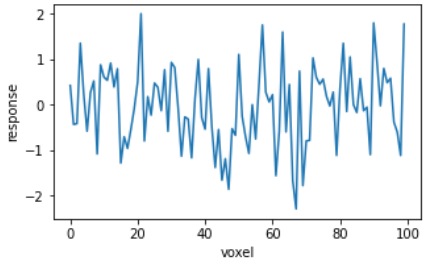
Correlation Coefficients of Voxel Variables



Correlation Power



Analysis – Decoding



Logistic Regression (Family: Binomial),

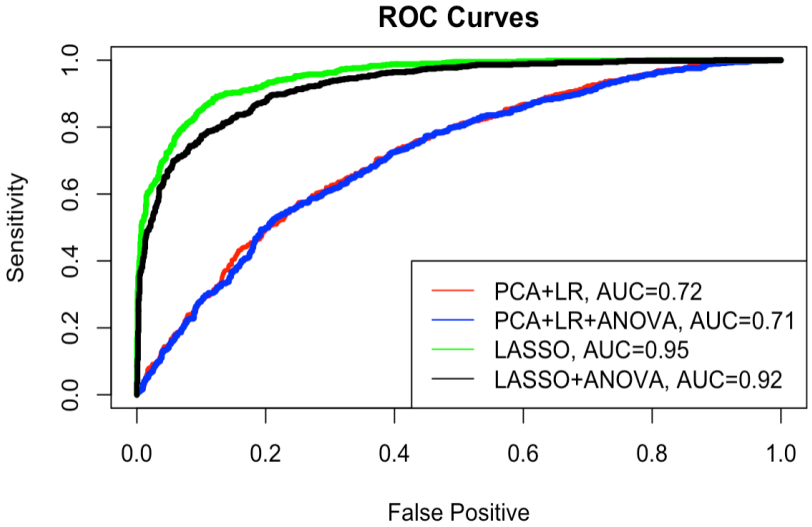
Formula: Classes ~ Voxels

Classes of the Image:

1. Animal
2. Not Animal

Classification Methods

1. PCA + Logistic
2. PCA + Logistic + ANOVA
3. **LASSO Logistic**
4. LASSO Logistic + ANOVA



Analysis – Decoding

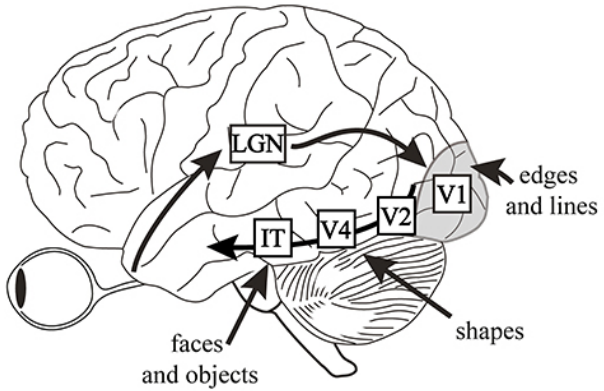
Classification Methods	Training Accuracy	Testing Accuracy
1. PCA + Logistic	0.69	0.483
2. PCA + Logistic + ANOVA	0.692	0.517
3. LASSO Logistic	**0.883**	**0.65**
4. LASSO Logistic + ANOVA	**0.855**	**0.675**

Analysis – Decoding

Final Model: **LASSO LR** (highest training accuracy, almost highest testing accuracy, highest AUC)

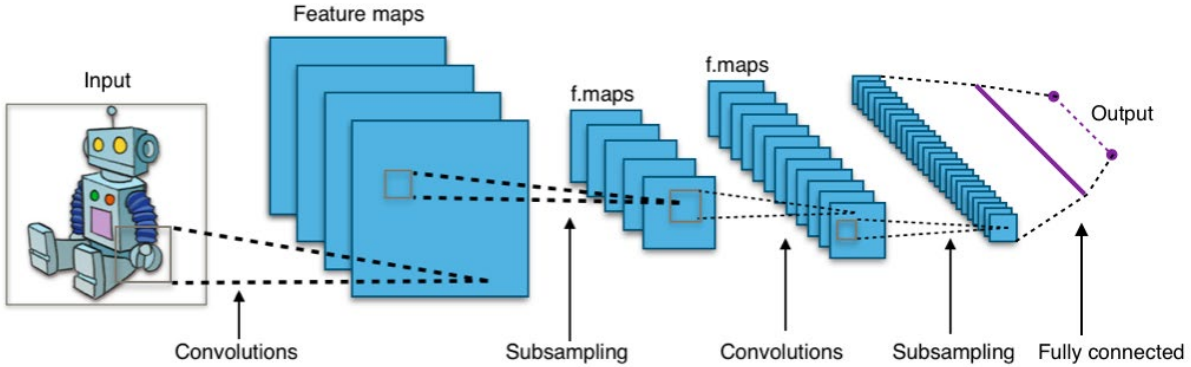
Ranking of regions in affecting prediction accuracy (7-most important; 1-least important)

Order	Region
7	**IT**
6	**V3**
5	**V4**
4	V3A
3	V3B
2	V2
1	V1

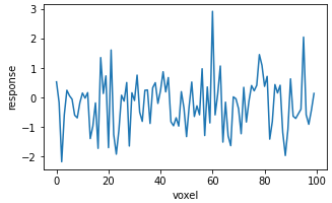


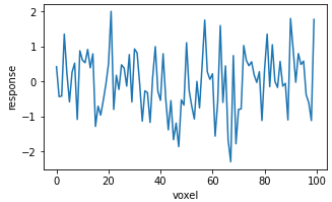
Finding: The most important regions for classification are the **higher cortical regions** of visual systems.

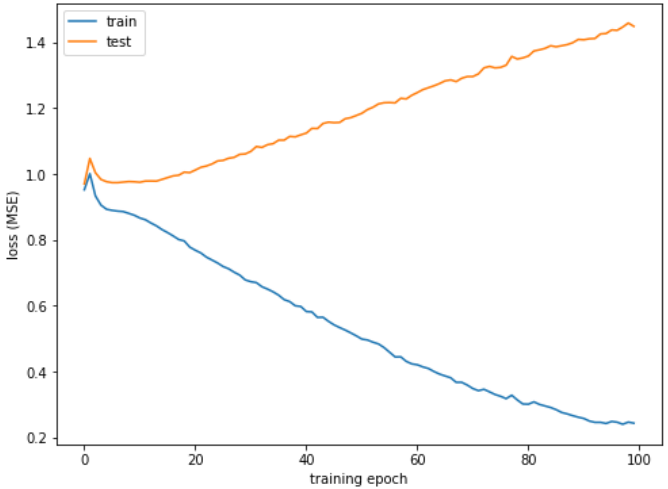
Analysis – Convolution Neural Network



https://ysjournal.com/medical-image-translation-using-convolutional-neural-networks/

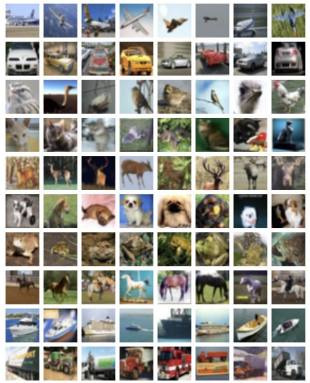


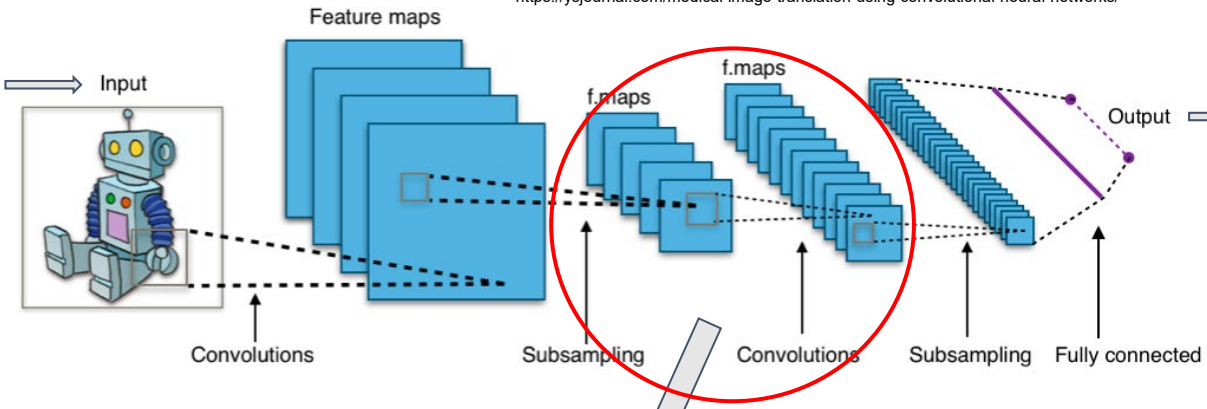




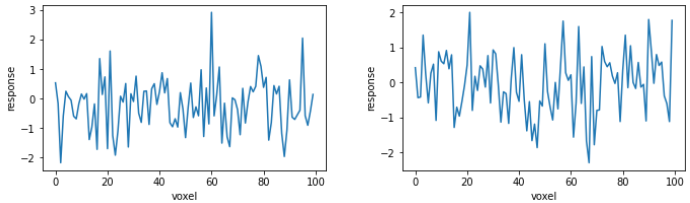
Analysis – Issue with Overfitting

CIFAR 10

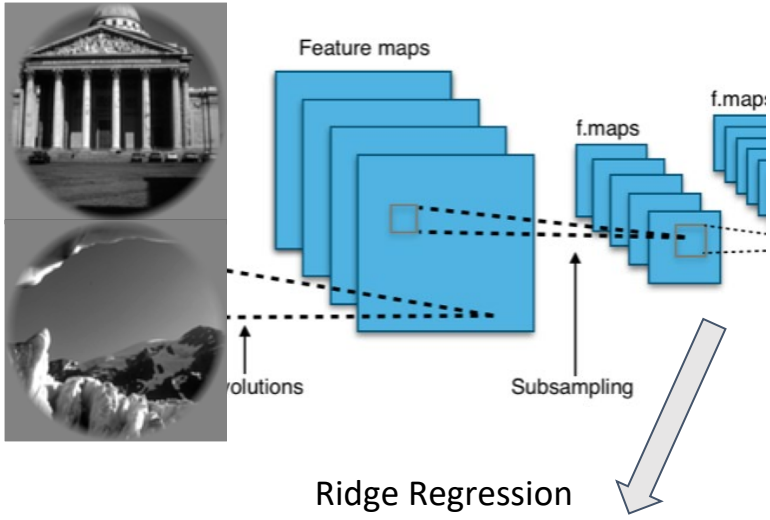




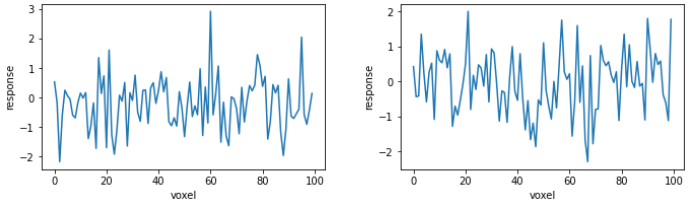
Ridge Regression
Cross-validation to select lambda



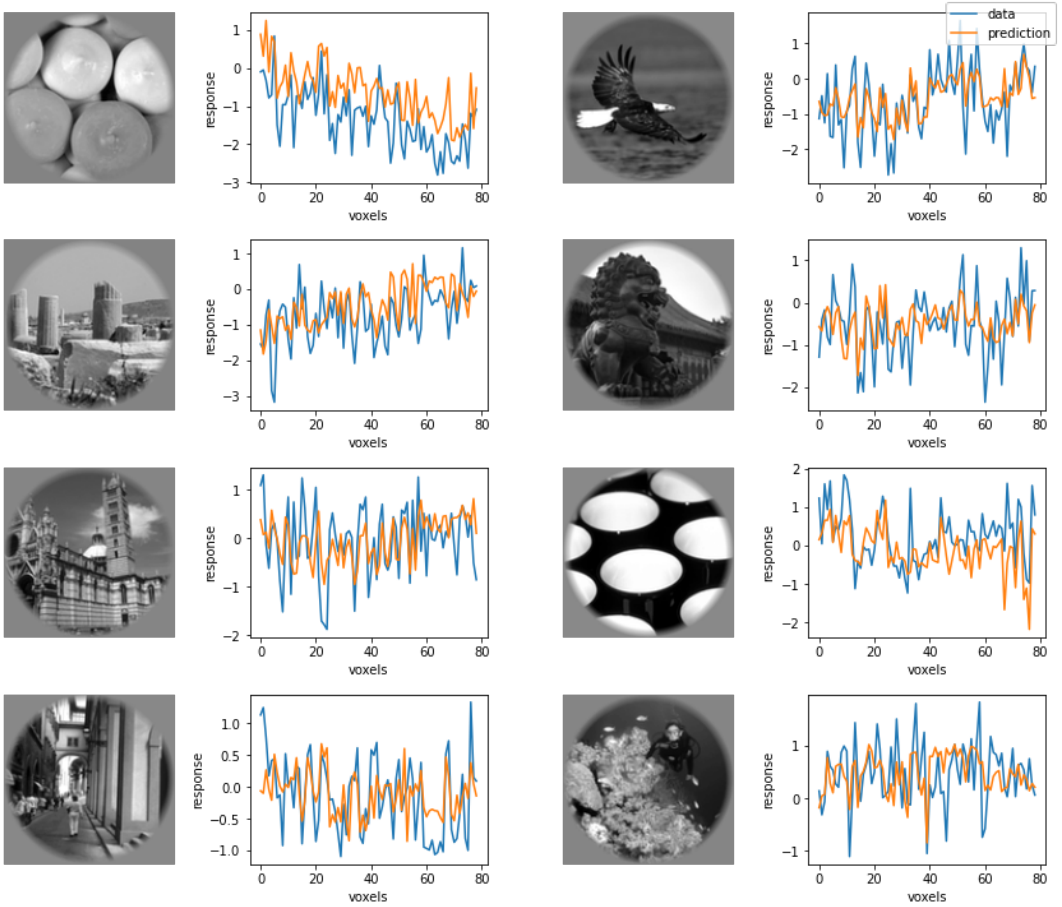
Analysis – Convolution Neural Network Encoding



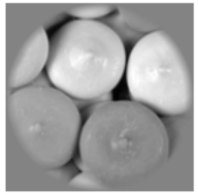
Ridge Regression

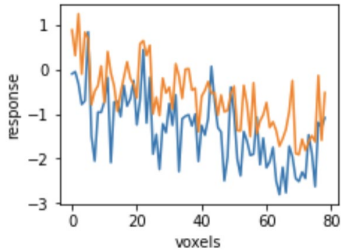


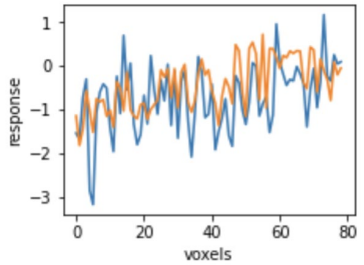
V1, V2, ~ 300 voxel; R-squared = 0.2

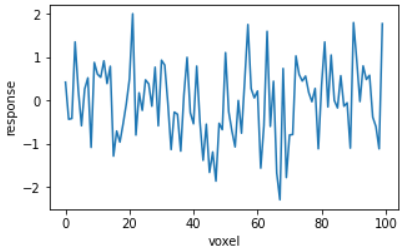


Analysis – Convolution Neural Network Decoding?

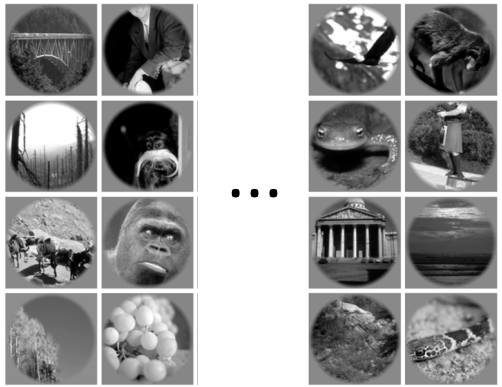




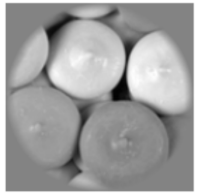


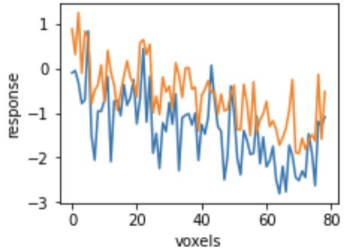


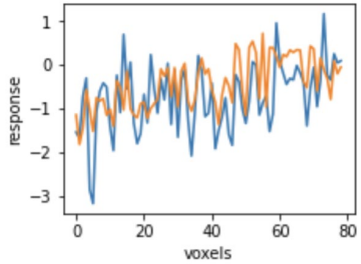
100 images (test set)



Analysis – Convolution Neural Network Decoding?







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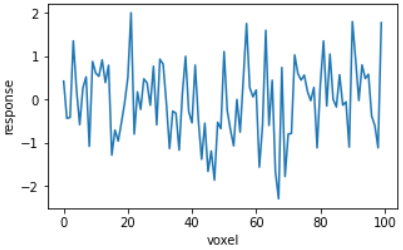
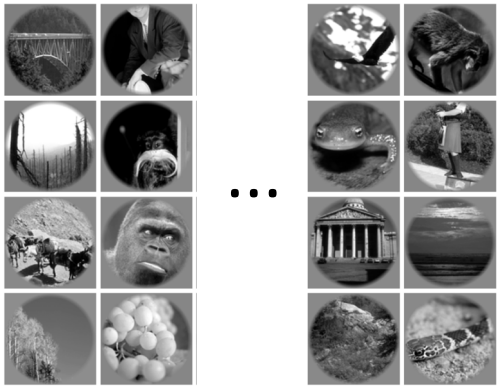
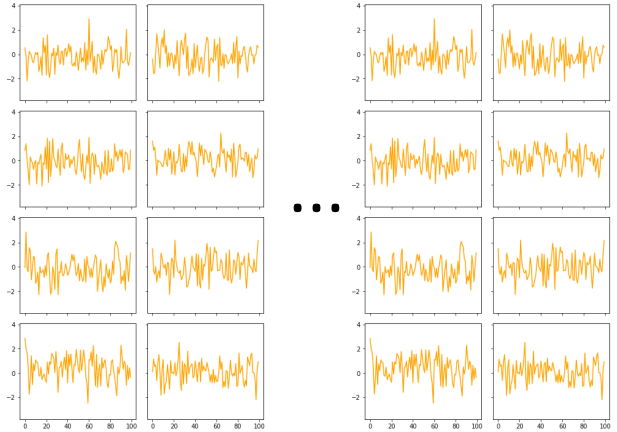
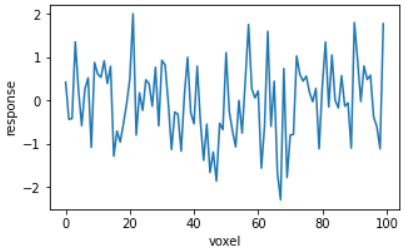


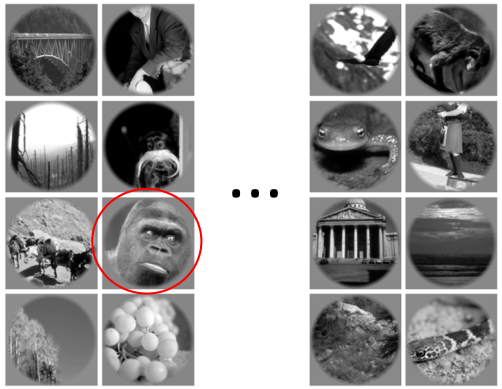


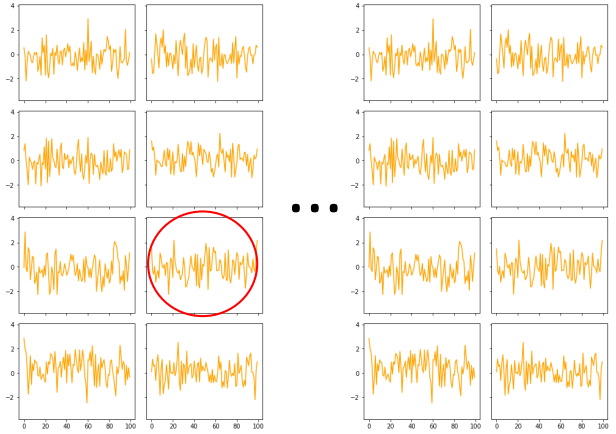


Analysis – Convolution Neural Network Decoding?

100 images



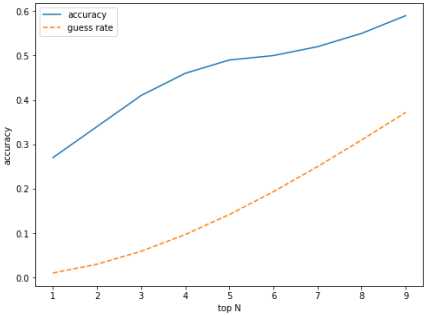




max similarity

Top-1 Accuracy: 29% (guess rate = 1%)

Top-5 Accuracy: 48% (guess rate ~ 14%)



Summary

Key Findings & Future Directions	
Key Findings	• A simple LASSO regression is able to read-out categorical information about the visual input from higher visual cortical activities • A pre-trained (on object recognition) convolution neural network can be a pretty good model of brain responses to images • The network can be used to “decode” visual image from brain activities
Future Directions	• More advanced decoding methods (i.e., non-linear regression, Bayesian hierarchical models) • Larger network with higher resolution input • Our current model is only predictable of lower cortical area; extend to higher cortical area

Thank you for your listening!

GitHub: https://github.com/lingqiz/STAT-571-DataMining/tree/main/Project