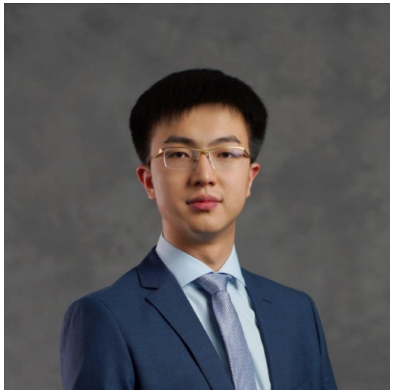
“Mind Reading”: Decode Visual Images from Brain Activities

Data Science Live – STAT 571/701

Shaolong Wu, Yuzhou Lin, Lingqi Zhang

Members



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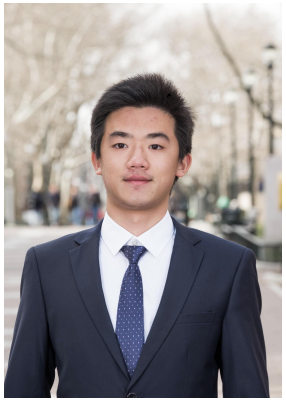
- **Hometown:** Nanjing, China
- **School:** Wharton, Engineering
- **Program:** BS in Economics, MSE in Electrical Engineering
- **Research Interests:** Econometrics



Yuzhou Lin

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

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

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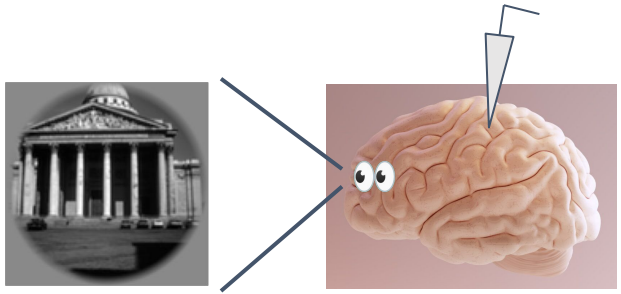
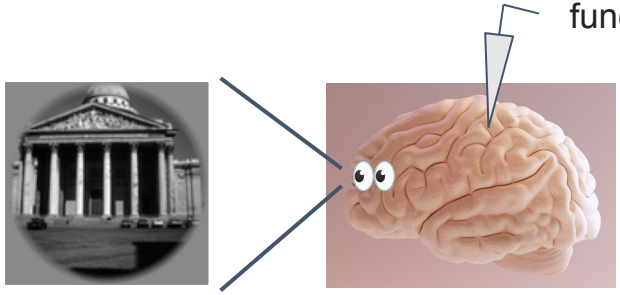
  ~ 100 billion neurons
  ~ trillions of connections (synapses)
  ~ 20% power, 20 W

- External stimulus - Brain activities
- Visual cortex

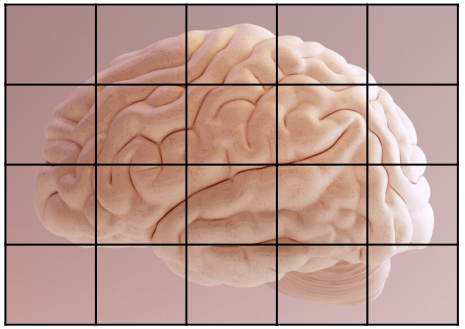


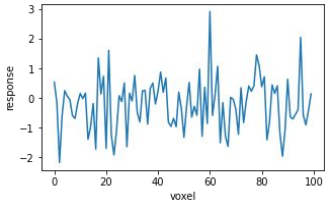
- Rehabilitation
- Build artificial visual system
- It’s really cool

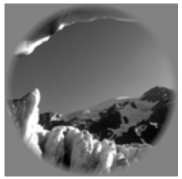
Introduction

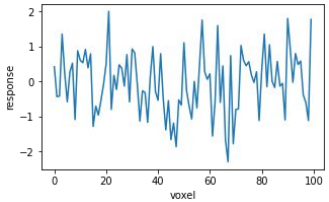


functional magnetic resonance imaging (fMRI)

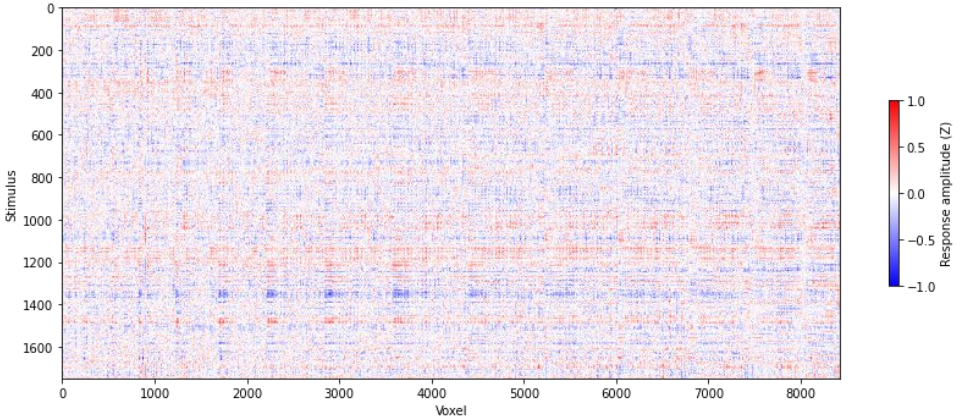






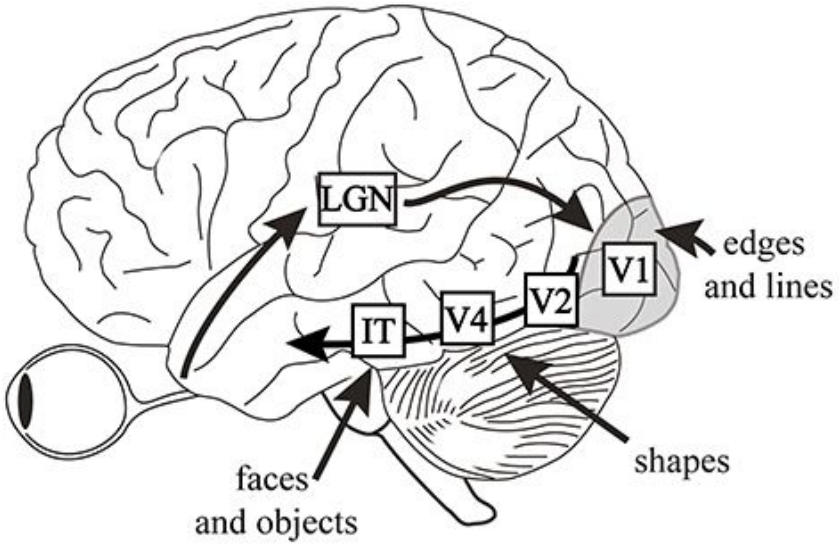


> 8000 voxel,
1750 images for training, 100 images for testing

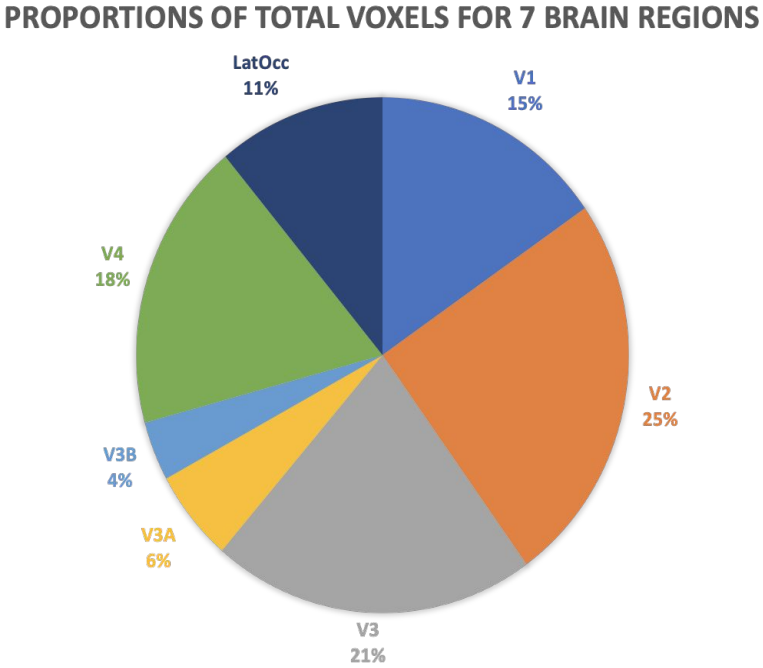


Introduction

Visual system is ***Hierarchical***

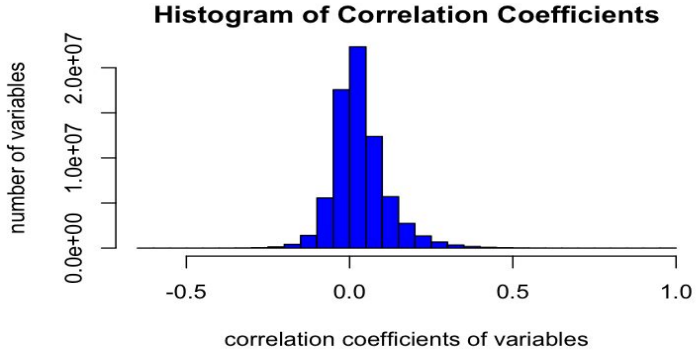


Herzog & Clarke, 2014

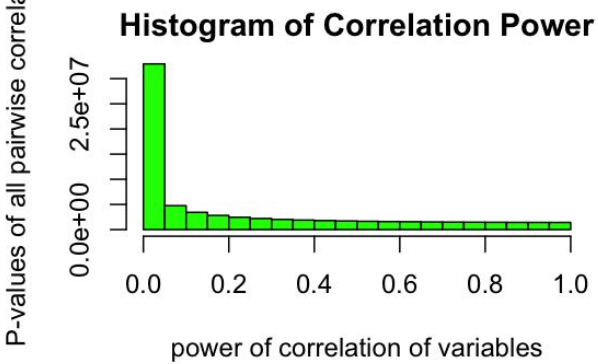


Exploratory Data Analysis

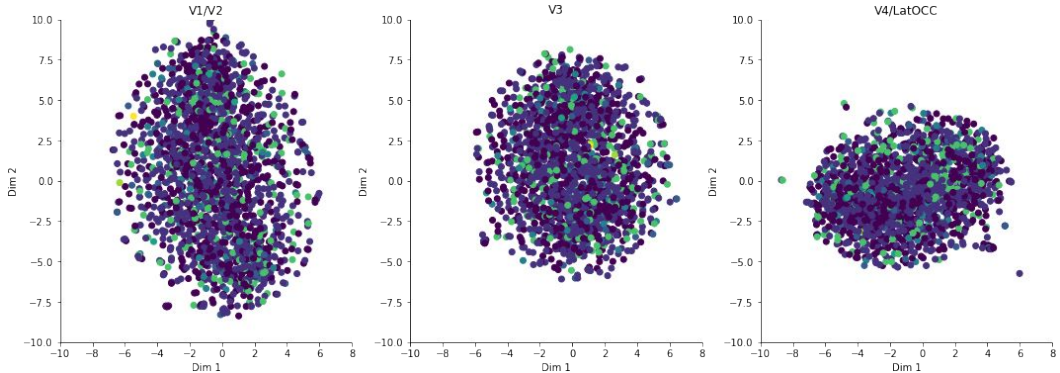
Correlation Coefficients of Voxel Variables



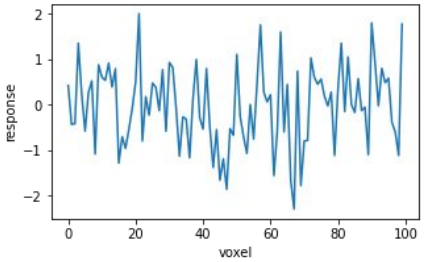
Correlation Power



Dimensionality Reduction



Analysis – Decoding



Logistic Regression (Family: Binomial),

Formula: Classes ~ Voxels

Classes for Objects:

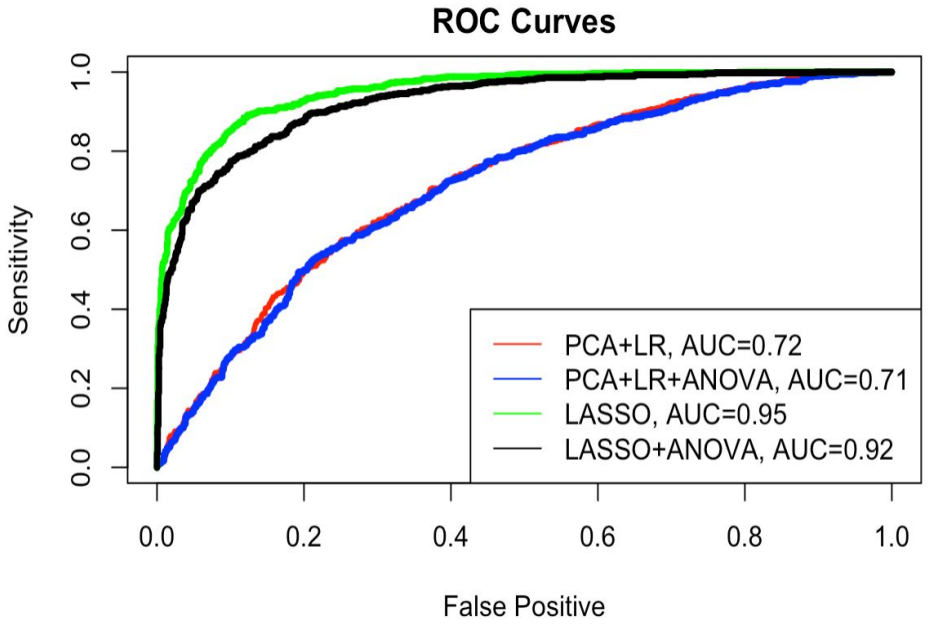
1. Animal
2. Not Animal

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

Analysis – Decoding

ROC Curve: shows the diagnostic ability of a binary classifier system as its discrimination threshold is varied.

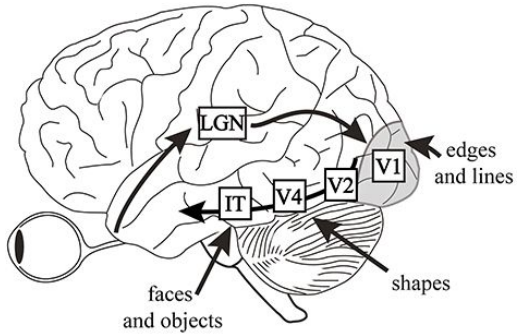
LASSO Model: The highest AUC



Final Model: **LASSO** (highest training accuracy in testing, highest AUC, testing accuracy high enough)

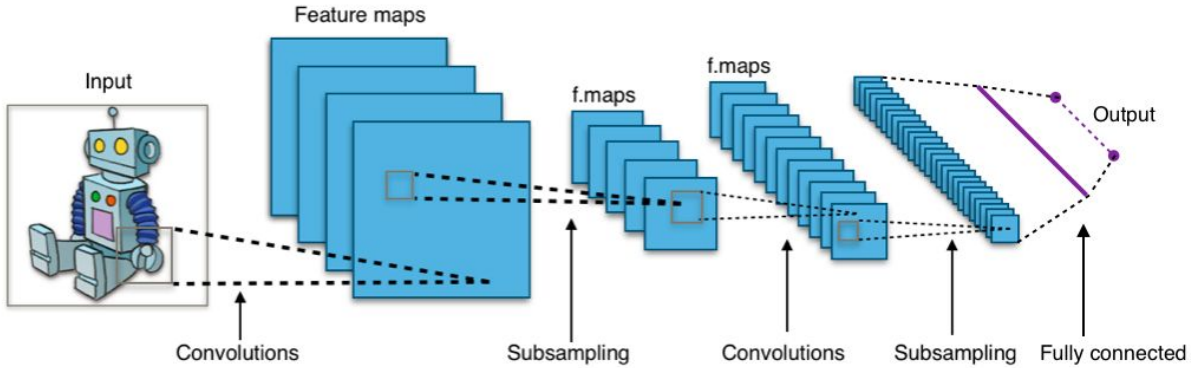
Ranking of regions in affecting prediction accuracy (7-most important; 1-least important)

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

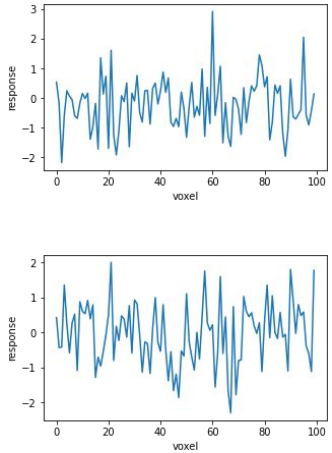


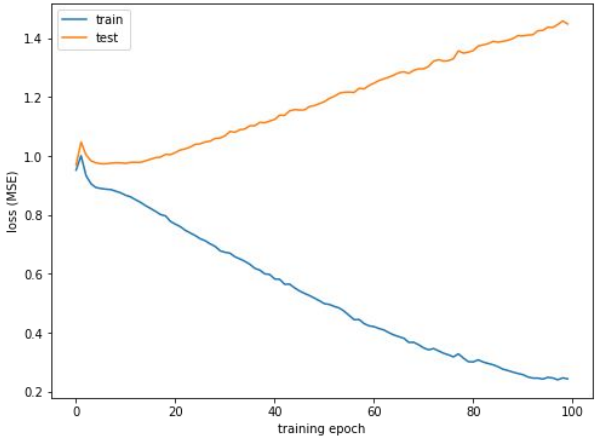
(every variable -- a voxel; obtain the ranking above by calculating the proportion of voxels included in the final model for each region)

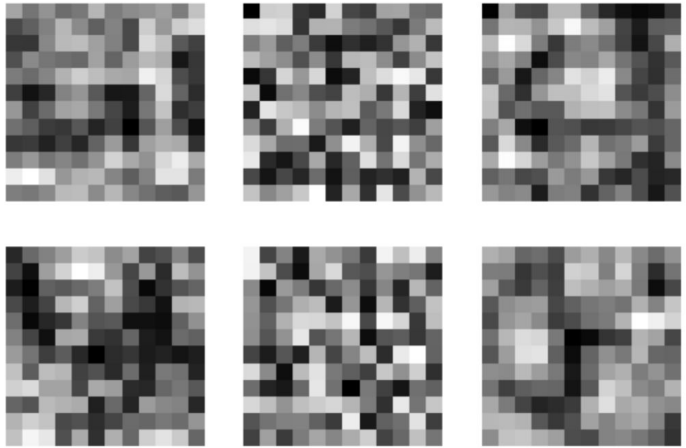
Analysis – Convolution Neural Network



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

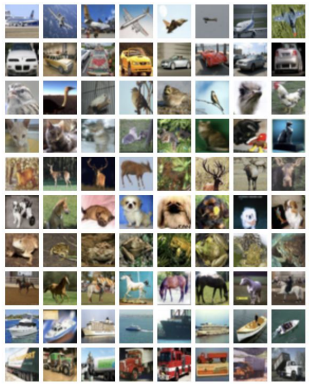






Analysis – Issue with Overfitting

CIFAR 10



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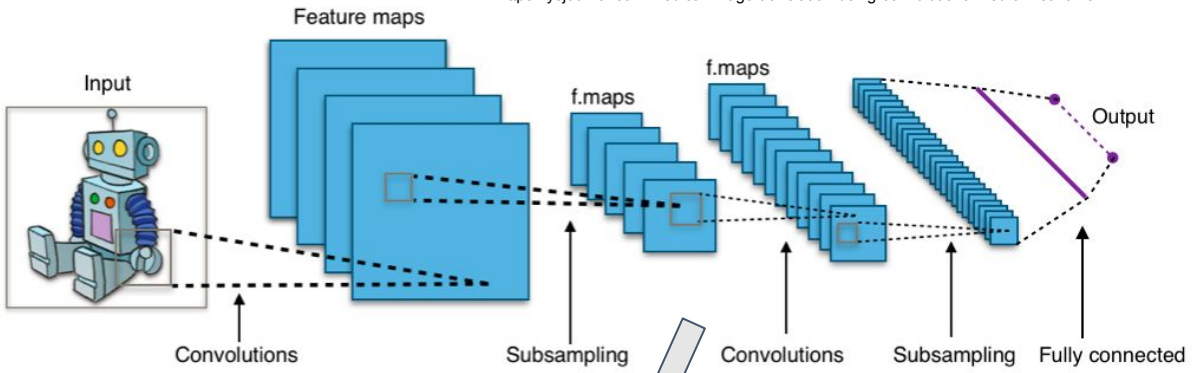


airplane

automobile

bird

cat

deer

dog

frog

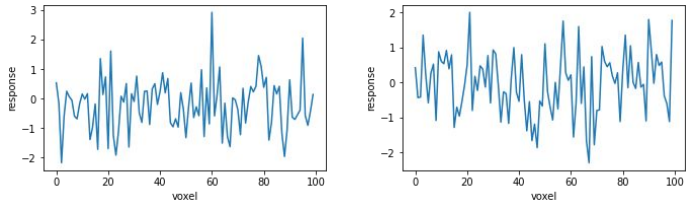
horse

ship

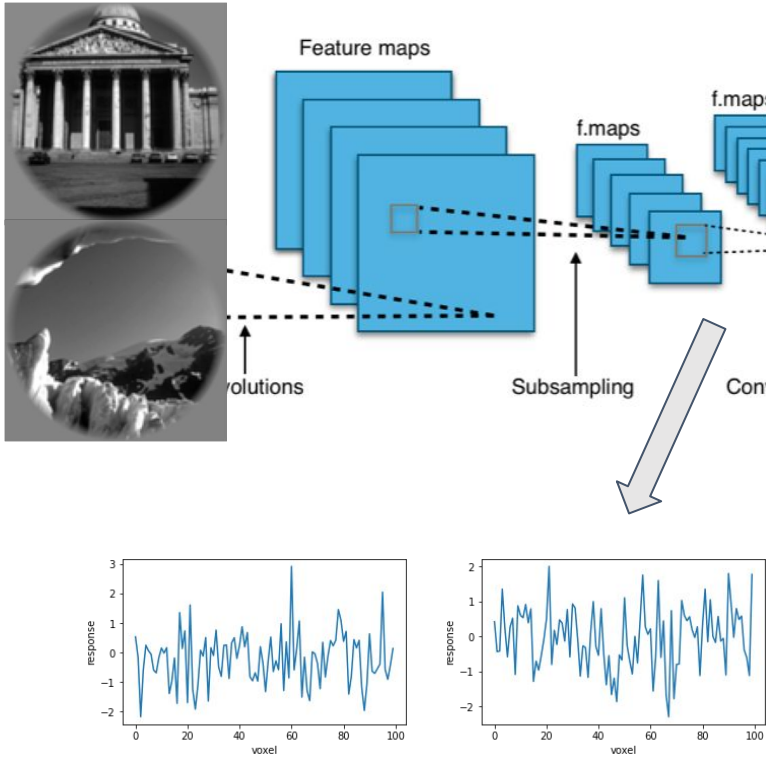
truck

Ridge Regression

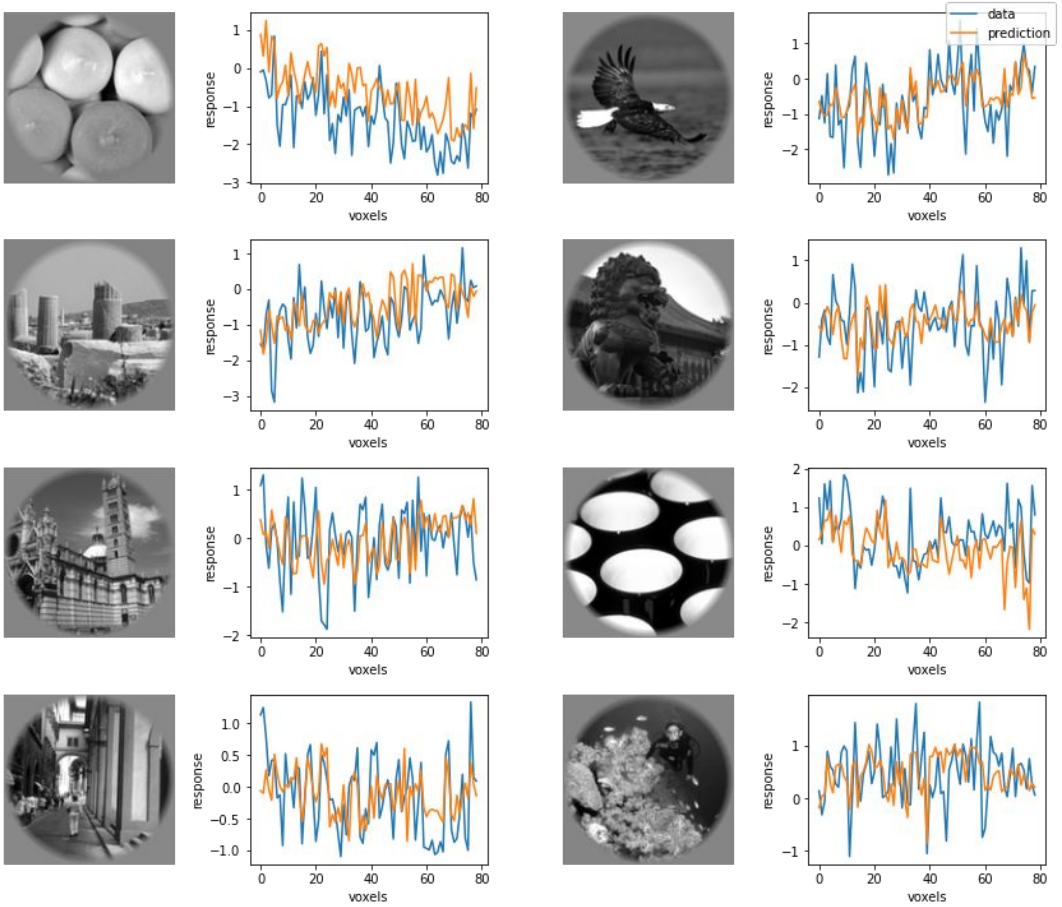
Cross-validation to select lambda



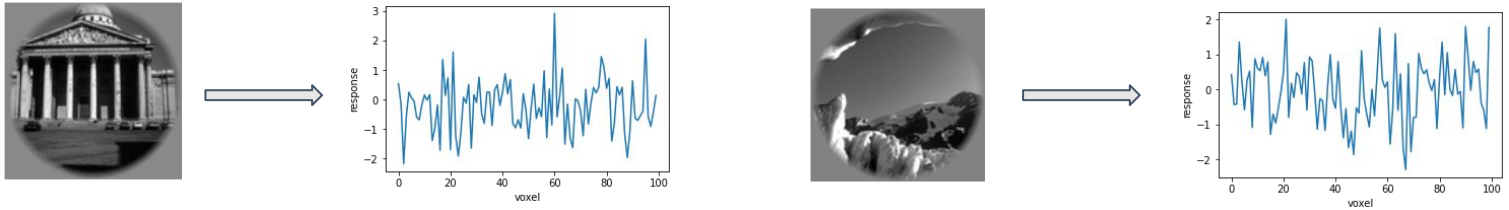
Analysis – Convolution Neural Network Encoding



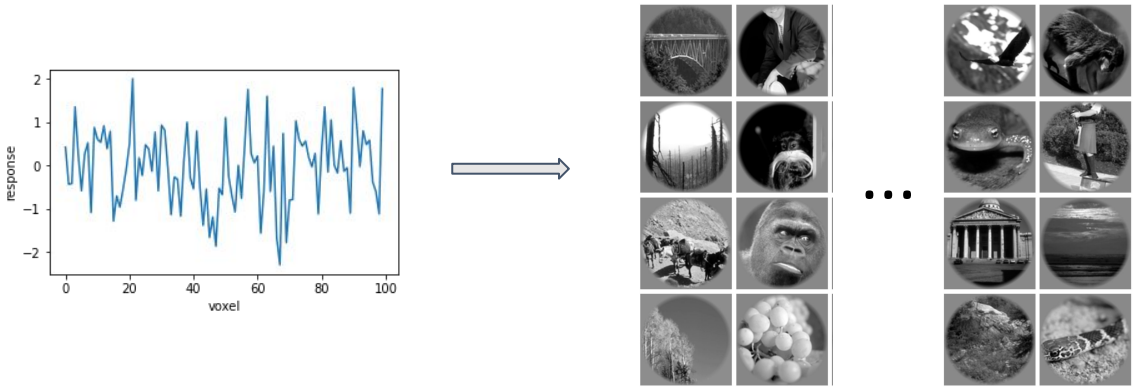
V1, V2, ~ 300 voxel; R2 = 0.2



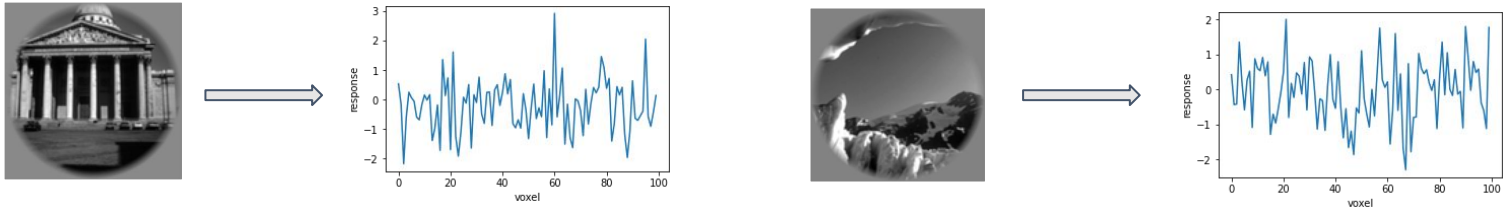
Analysis – Convolution Neural Network Decoding?



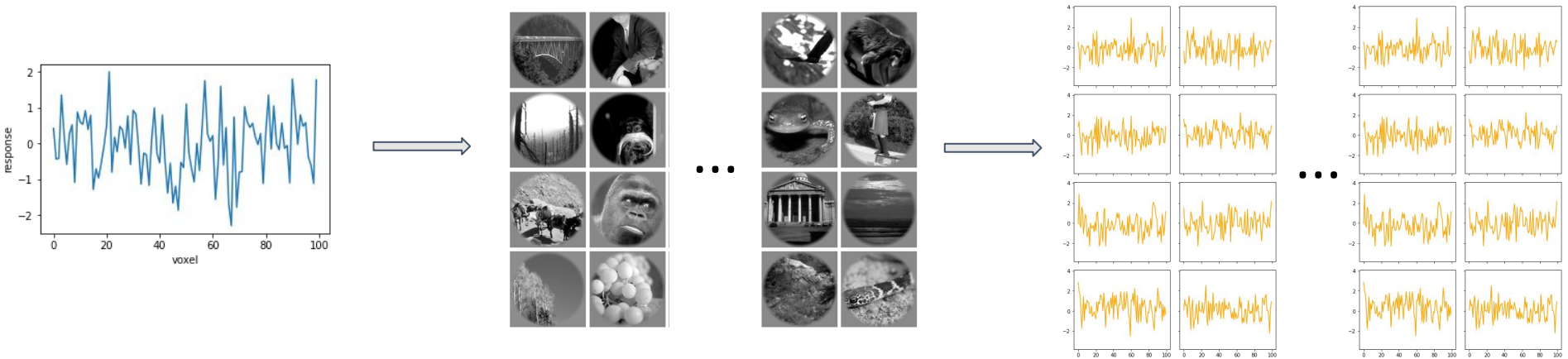
100 images



Analysis – Convolution Neural Network Decoding?

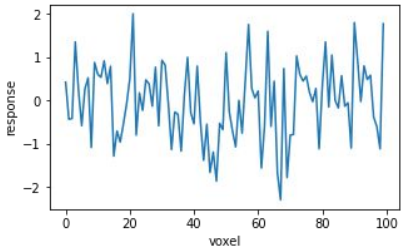


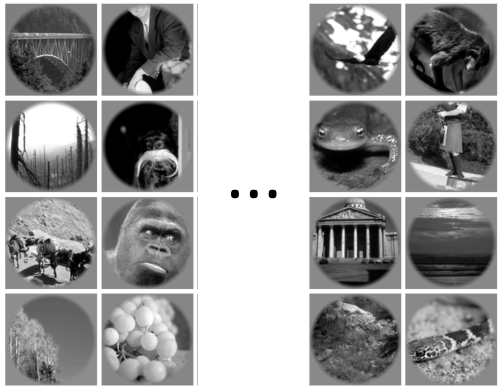
100 images

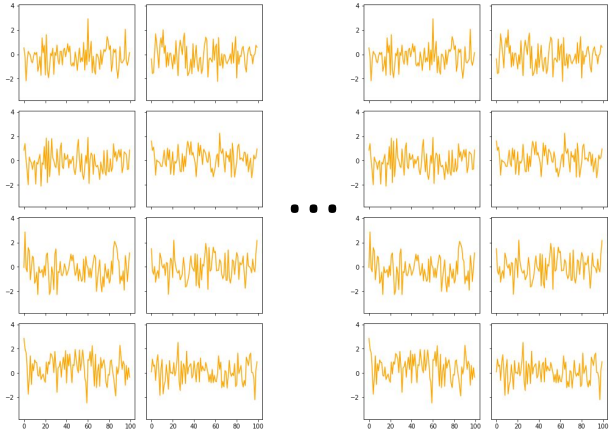


Analysis – Convolution Neural Network Decoding?

100 images



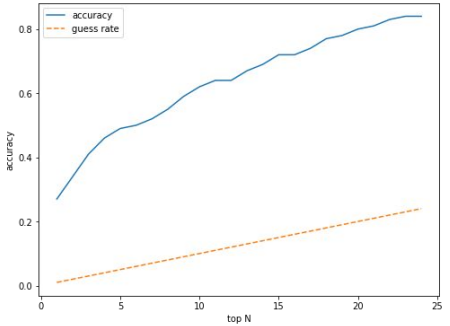




min error

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

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



Summary

Key Findings	• A simple LASSO regression is able to read-out categorical information about the visual input from **later 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 method (i.e., non-linear regression) • Our current model is only predictable of V1, V2: Extend to higher cortical area

Thank you for your listening!

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