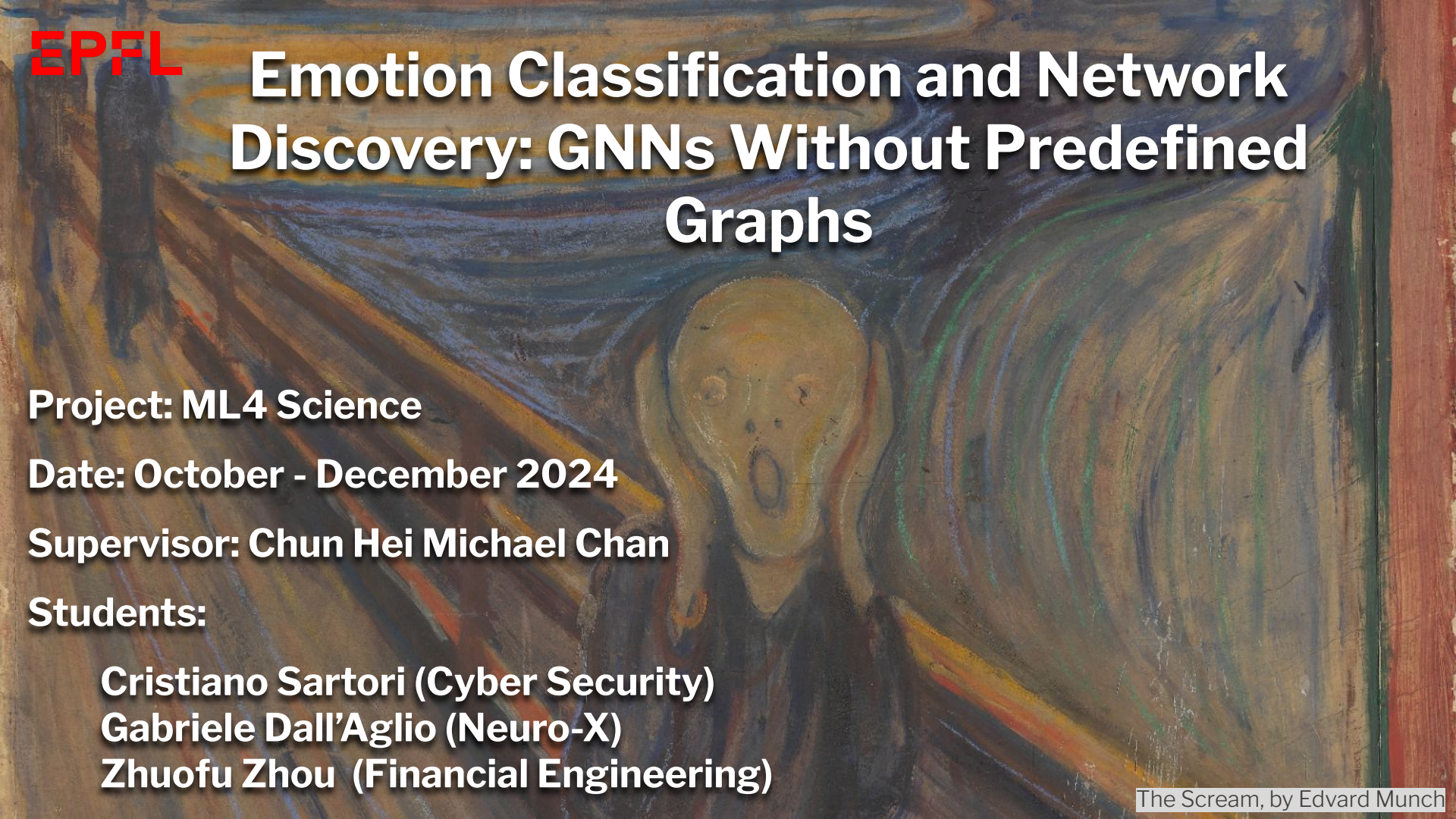


Emotion Classification and Network Discovery: GNNs Without Predefined Graphs

Project: ML4 Science

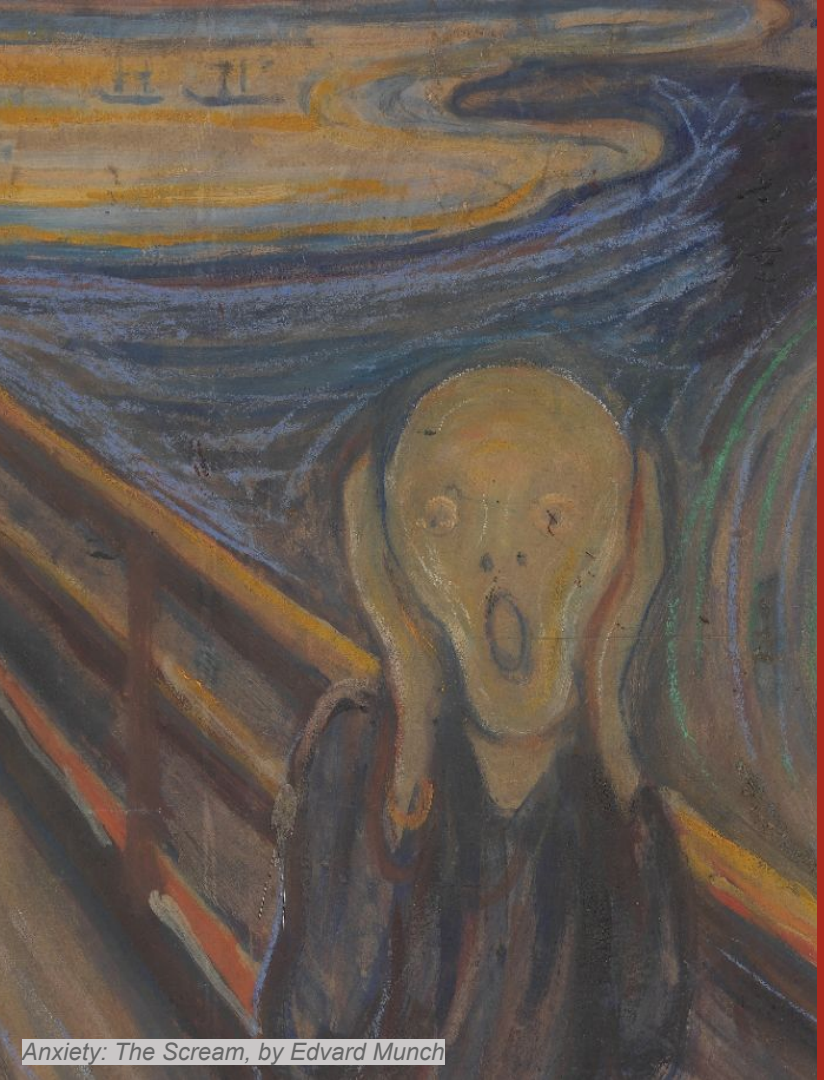
Date: October - December 2024

Supervisor: Chun Hei Michael Chan

Students:

Cristiano Sartori (Cyber Security)
Gabriele Dall'Aglio (Neuro-X)
Zhuofu Zhou (Financial Engineering)

The Scream, by Edvard Munch



Anxiety: The Scream, by Edvard Munch

Introduction and Goals

- Labels Processing
- Train Test Splitting
- Imputed Connectivity
- Baseline: RF, KNN, FNN, GCN
- GSL: GAT
- State of the art: VIB
- Conclusion

Introduction: Literature

Goal:
- Classification of Emotion
- Graph Structure Learning

Paradigm: Movie observation

Data: fMRI Recordings (Emo-FilM)
- Already Preprocessed
- Schaefer Parcellation + 14 deep regions

Models:
- Baselines Models
- Graph Neural Networks (GNN)

A systematic review on affective computing: emotion models, databases, and recent advances

Yan Wang [a], Wei Song [c], Wei Tao [a], Antonio Liotta [d], Dawei Yang [a], Xinlei Li [a], Shuyong Gao [b], Yixuan Sun [a], Weifeng Ge [b], Wei Zhang [b], Wenqiang Zhang [a,b,*]

Probing neurodynamics of experienced emotions—a Hitchhiker's guide to film fMRI

Elenor Morgenroth, [1,2,3] Laura Vilaclara, [1,2] Michal Muszynski, [4] Julian Gaviria, [3,4,5] Patrik Vuilleumier, [3,4,6] and Dimitri Van De Ville [1,2,6]

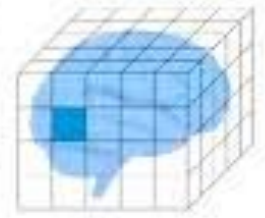
Emo-FilM: A multimodal dataset for affective neuroscience using naturalistic stimuli

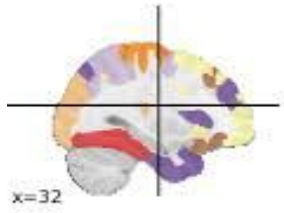
Elenor Morgenroth, Stefano Moia, Laura Vilaclara, Raphael Fournier, Michal Muszynski, Maria Ploumitsakou, Marina Almató-Bellavista, Patrik Vuilleumier, Dimitri Van De Ville

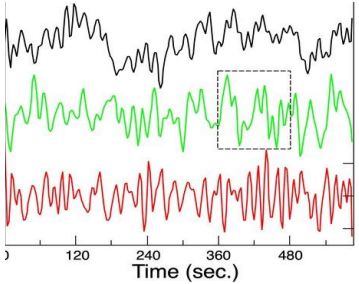
Emotion Recognition from Physiological Channels Using Graph Neural Network

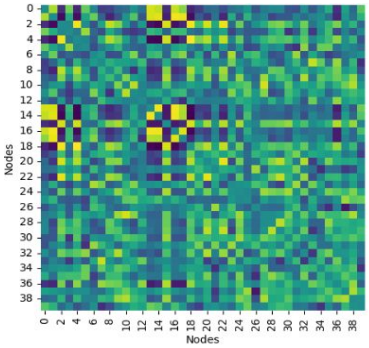
Tomasz Wierciński [1,*], Mateusz Rock [2], Robert Zwierzycki [2], Teresa Zawadzka [1] and Michał Zawadzki [3]

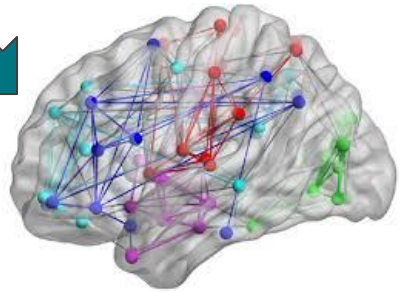
Introduction







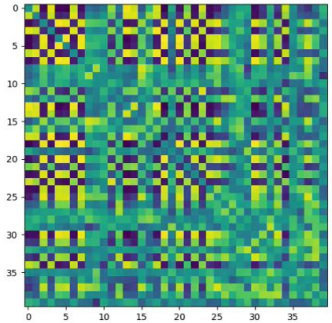




Imputed Graph

Deep Learning Model (GCN, GAT, ...)

Predicted Label
y_n = “Anger”



Problematics

fMRI Data

- Relatively new for Emotion Analysis
- Field richer with EEG
- Less Temporal Resolution

Why fMRI?

- Deeper region of the brain
- Spatial Information exploitable
- Resolution for smaller Regions

Happiness: Democritus, by Johannes Paulus Moreelse

- Introduction and Goals
- **Labels Processing**
- Train Test Splitting
- Imputed Connectivity
- Baseline: RF, KNN, FNN, GCN
- GSL: GAT
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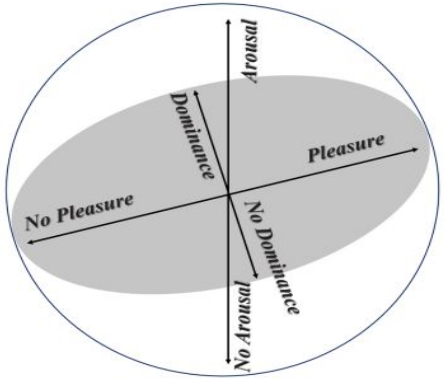
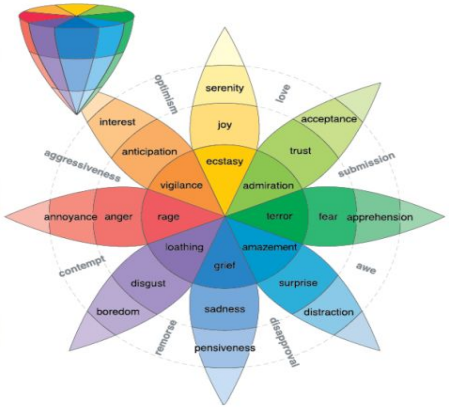
Labels Processing

Regression

Geometry-based FER





Classification

Plutchik's emotional wheel

Our Labels: Classification

- Subset emotions to 13 (from 50)
- Assign to each TR emotion with highest absolute value score
- Labels aligned using a shift of 4 TR (BOLD)

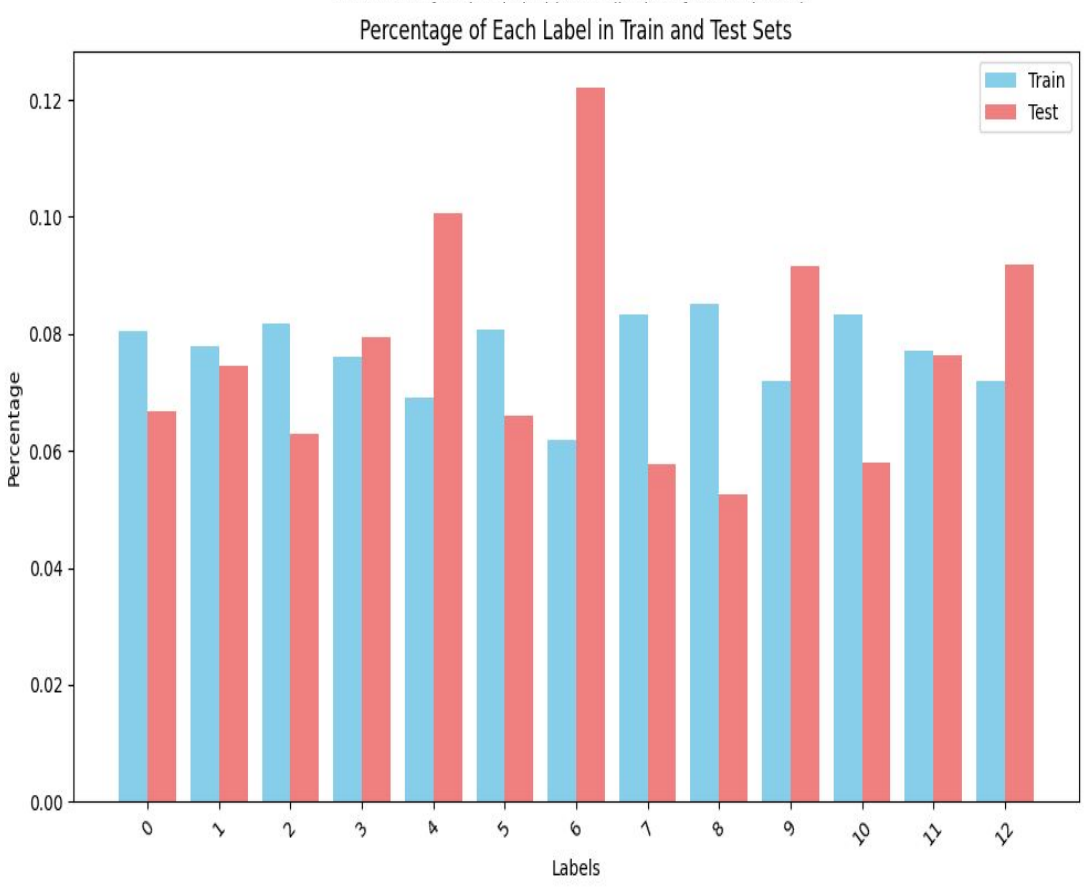
Train Test Splitting

Problem 1:
- Unbalanced Dataset

Problem 2:
- Different Proportion in Movies

Problem 3:
- Label Dependency

Approaches:
- Random splitting
- Horizontal split
- Vertical Split



Imputed Connectivity

Edge Attributes

Constant Value

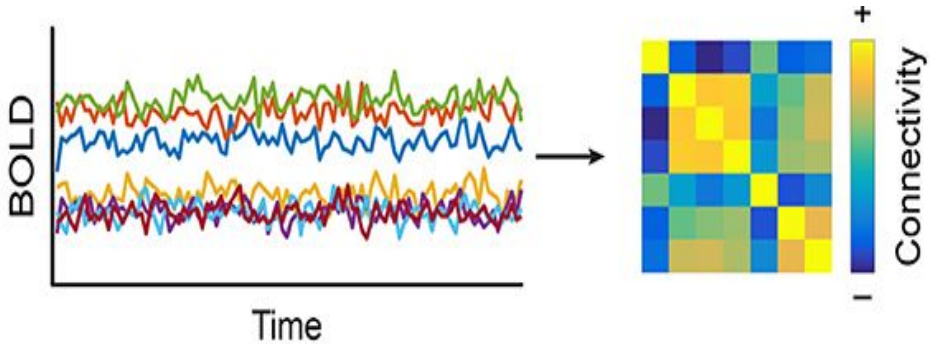
- 1
- 0 → Only self Loops
- FC whole movie

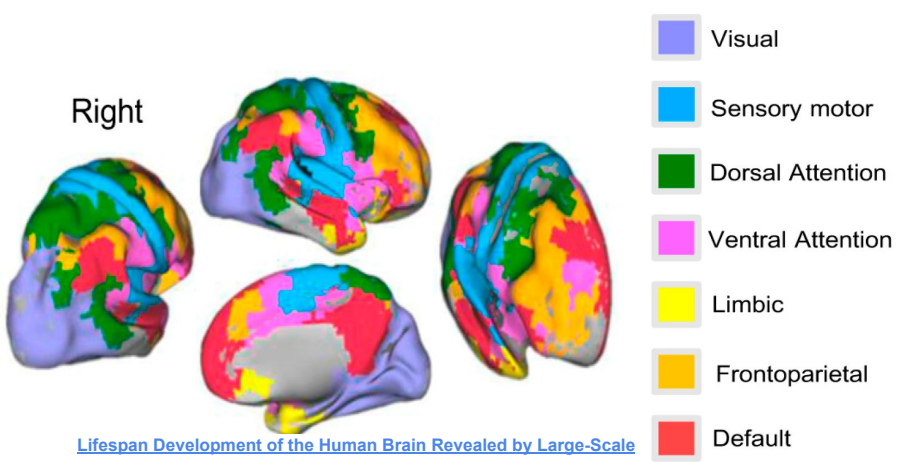
Dynamic Value

- FC Sliding window
- Variable window size

Nodes

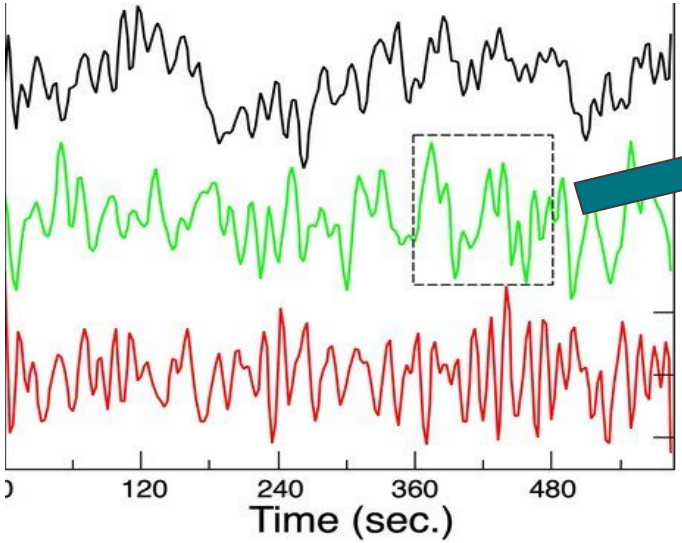
- All 414
- Specific Functional Network (FN)

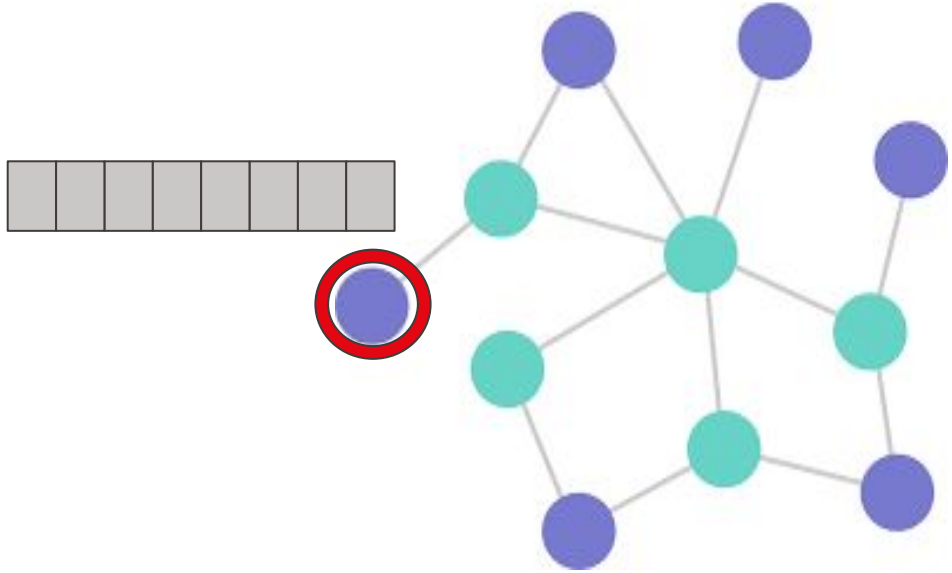




Lifespan Development of the Human Brain Revealed by Large-Scale Network Eigen-Entropy

Nodes Features





Sadness: Weeping Woman, by Picasso

- Introduction and Goals
- Labels Processing
- Train Test Splitting
- Imputed Connectivity
- **Baseline: RF, KNN, FNN, GCN**
- GSL: GAT
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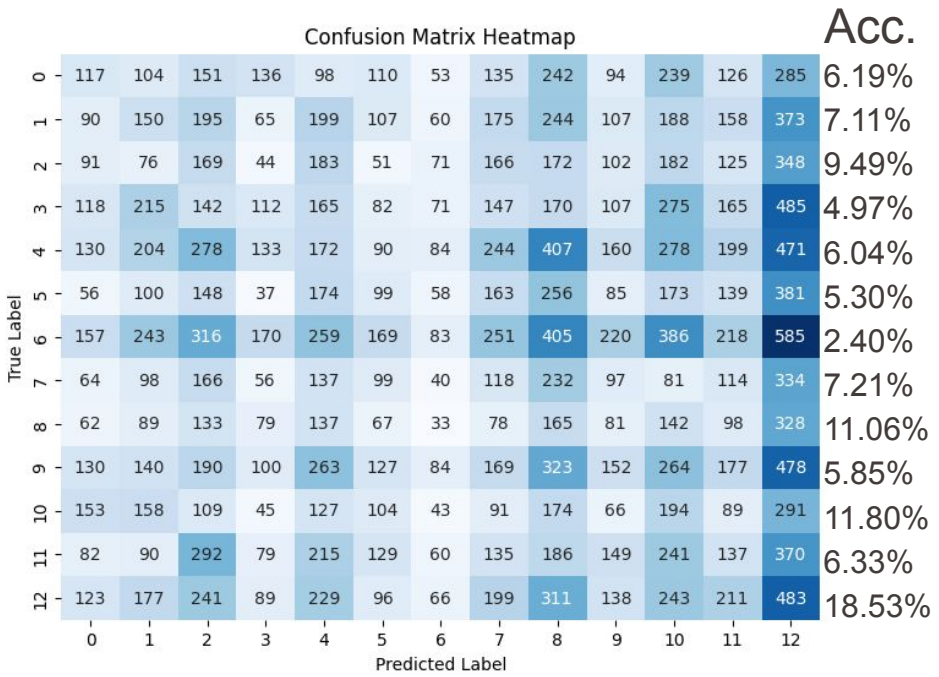
Baseline Methods

- Random Forest
- KNN
- Hand-Crafted Features

Feedforward Network (FNN):

- batch_size x (window x nodes)
- 3 Hidden Layers
- ReLu Activation
- Trainable params: 6,072,213

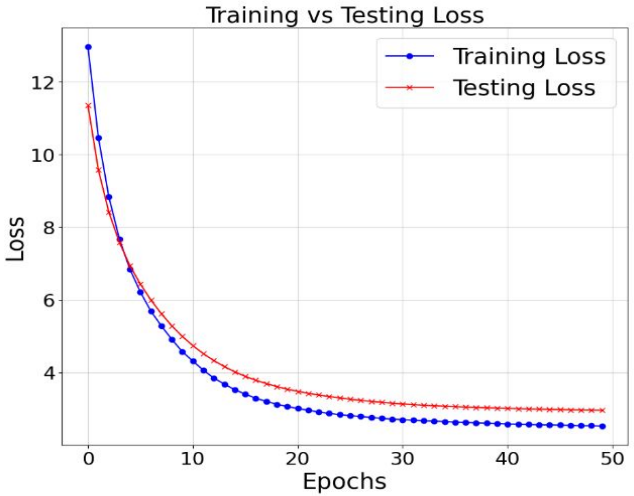


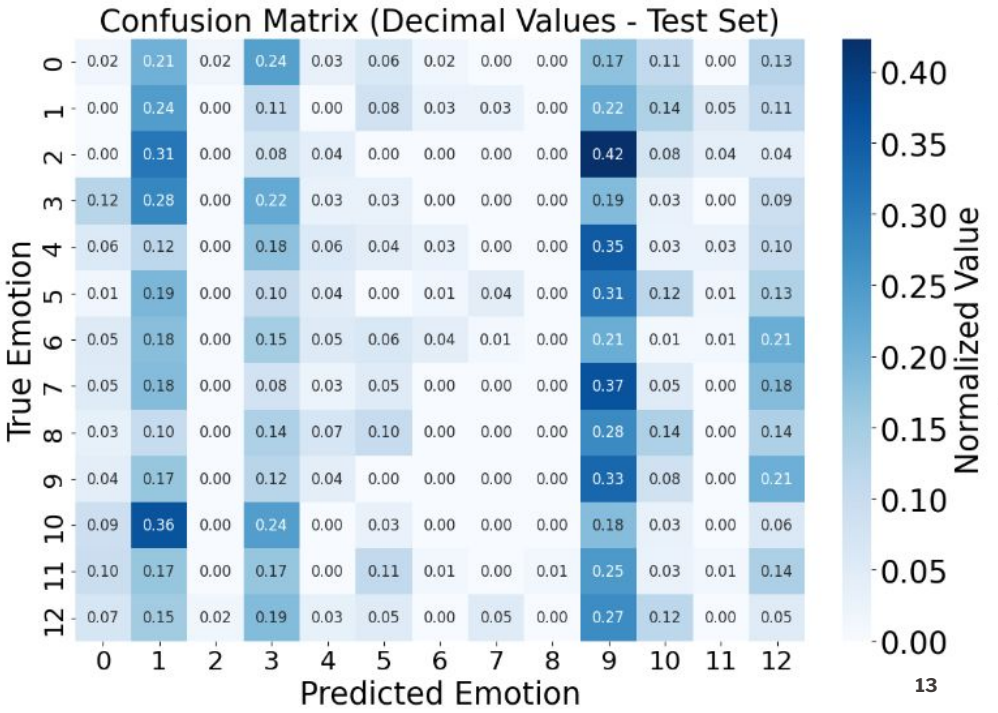
GCN - Graph Convolutional Network

Architecture Best Model:

- Adaptable Number Conv. Layers
- Dropout with 50%
- ReLu Activation
- Global Max Pooling

Results on Test: 5.91% Accuracy





Anger: The buyers and the sellers outside of the temple, by Gustave Doré

- Introduction and Goals
- Labels Processing
- Train Test Splitting
- Imputed Connectivity
- Baseline: RF, KNN, FNN, GCN
- **GSL: GAT**
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- Conclusion

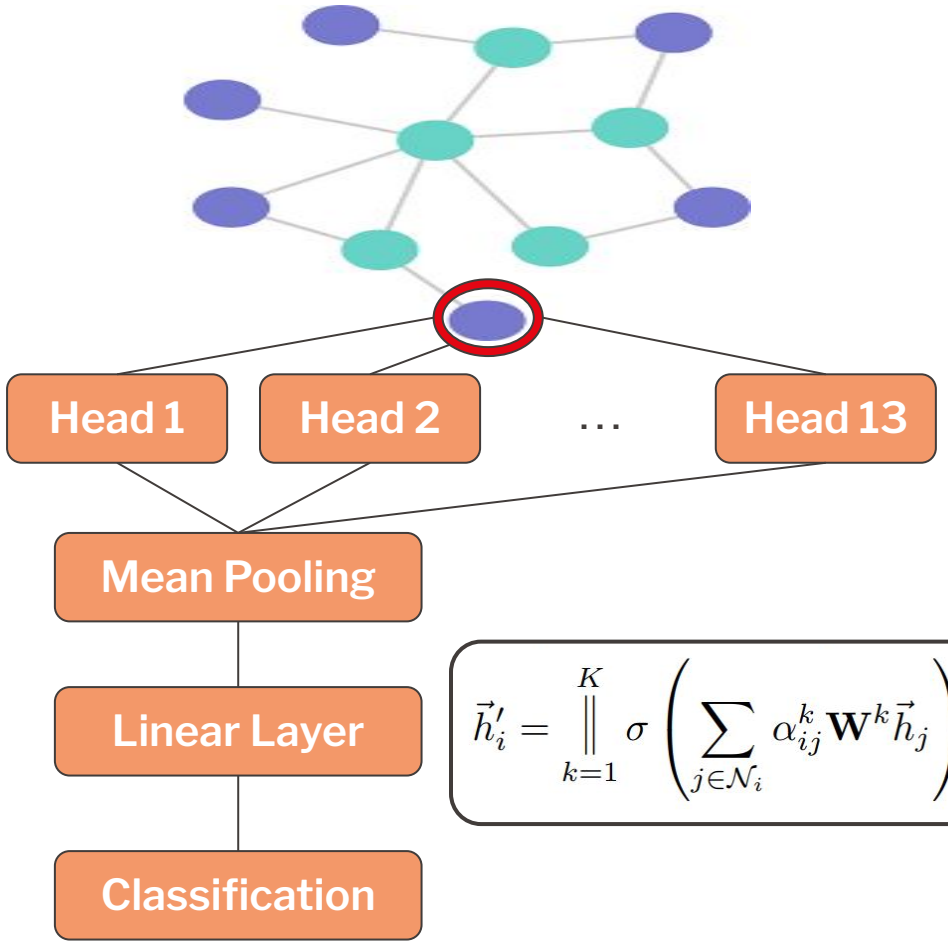
GAT

GAT == GNN with Attention Mechanism

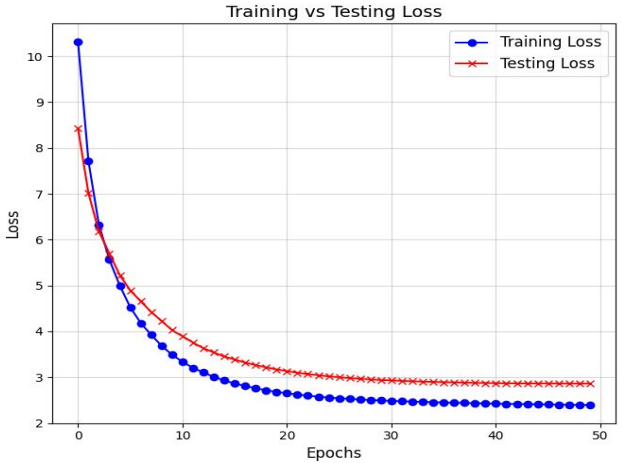
Architecture 13 Heads

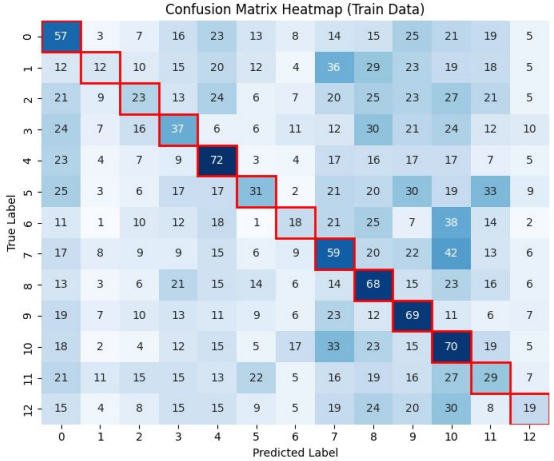
Why GAT:

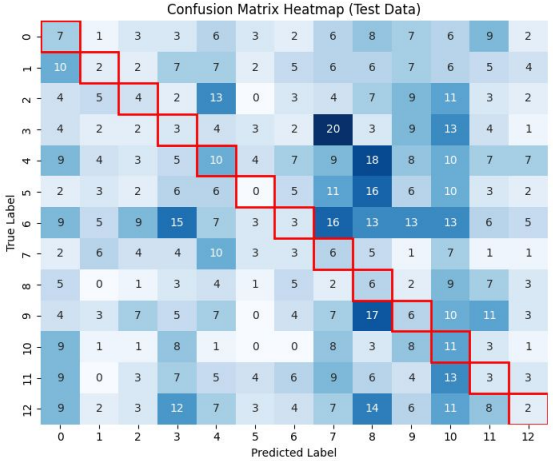
Interpretability of Attention Weights

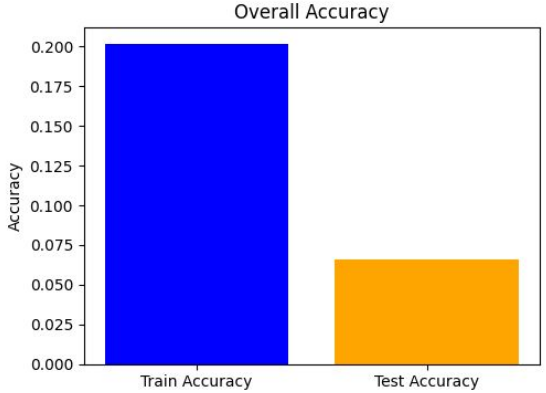


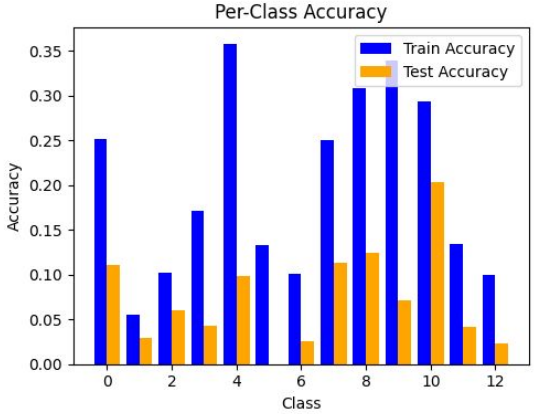
All movie, 1 subject, edge Attributes = FC









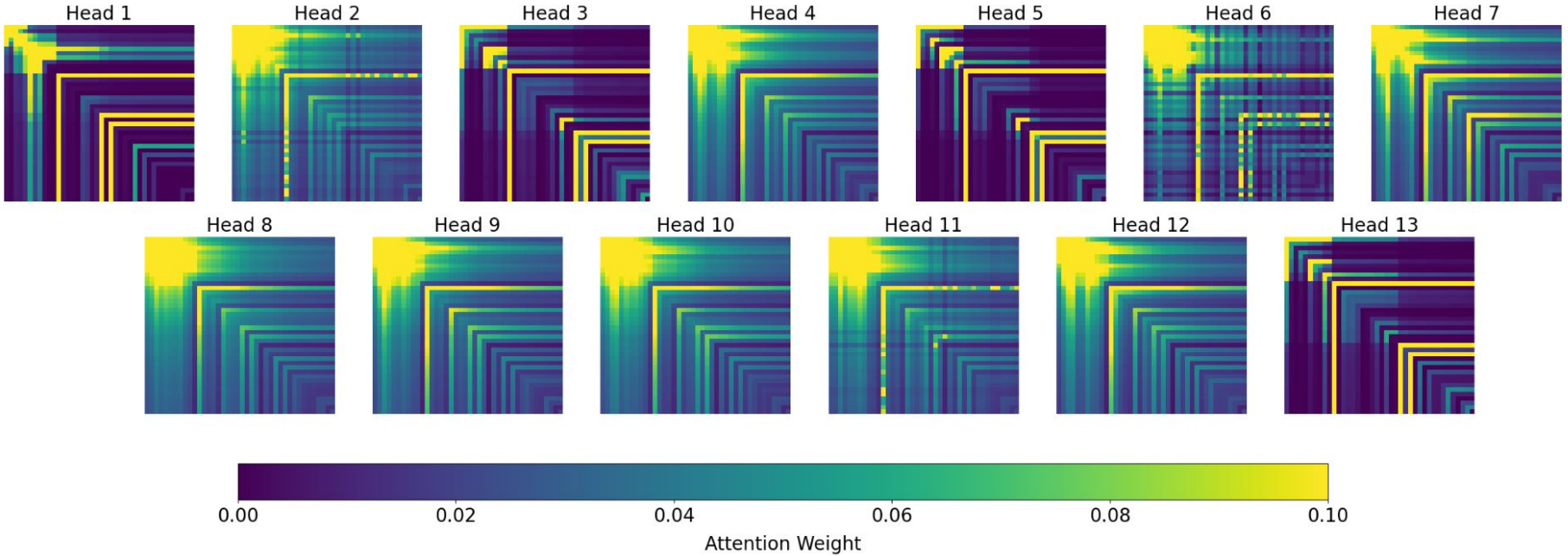


Grid-Search GAT

Hyperparameters	Accuracy Test
Window Size = 5, Adj Matrix Imputation: Clique, learning rate: 0.1, batch size: 32	8.88%
Window Size = 10, Adj Matrix Imputation: Clique, learning rate: 0.1, batch size: 32	7.04%
Window Size = 10, Adj Matrix Imputation: FN, learning rate: 0.1, batch size: 32, FN: Limbic	9.75%
Window Size = 5, Adj Matrix Imputation: FN, learning rate: 0.1, batch size: 32, FN: Visual	7.25%
...	...

?? Learnt Graphs ??

Attention Weights for Limbic FN




Surprise: La Surprise, by Joseph Ducreux

Introduction and Goals

Labels Processing

Train Test Splitting

Imputed Connectivity

Baseline: RF, KNN, FNN, GCN

GSL: GAT

State of the art: VIB

Conclusion

Why VIB

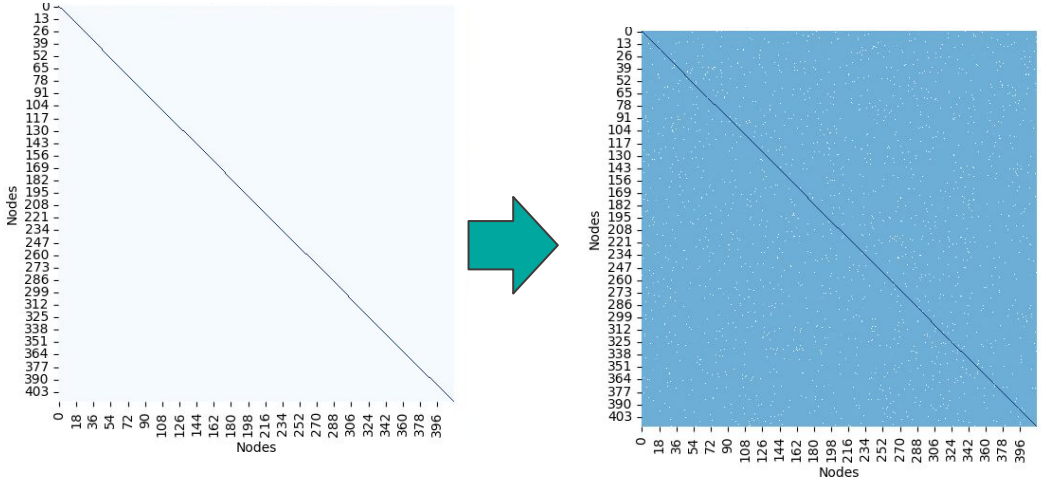
- Used on similar dataset
- State of the art Model
- GSL (KNN, Probabilities)
- Hyperparameters

Interpretable

Learn new graph for each Sample

Graph Structure Learning with Variational Information Bottleneck

Qingyun Sun[123], Jianxin Li[12], Hao Peng[1], Jia Wu[4], Xingcheng Fu[12], Cheng Ji[12], Philip S. Yu[5]



VIB: GSL + Variational Information Bottleneck

Input
Initial Graph

Graph Learning
- Learnable feature mask
- Calculate similarity between nodes
- construct a new graph

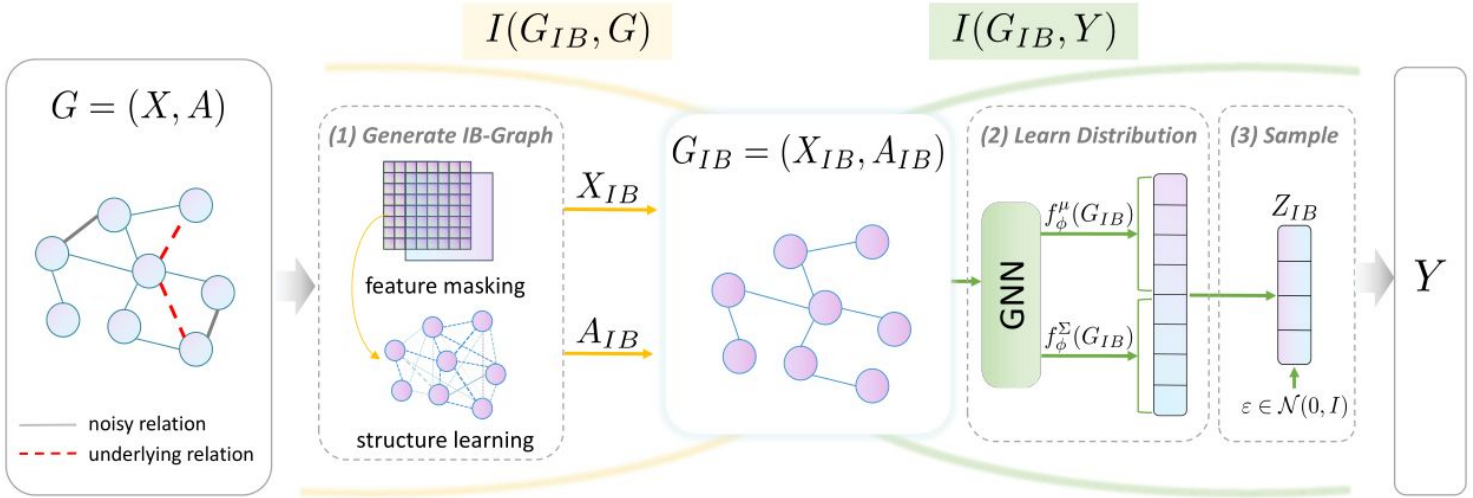
GNN
- GAT
- GIN
- GCN

Mean Pooling

Reparam etrization Trick

Linear layer

Output
Final Graph Label



Example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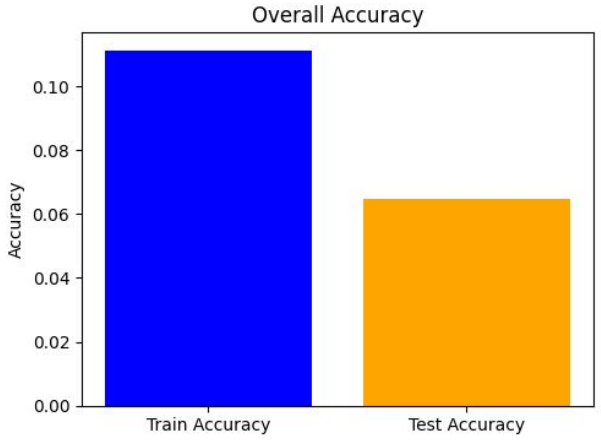
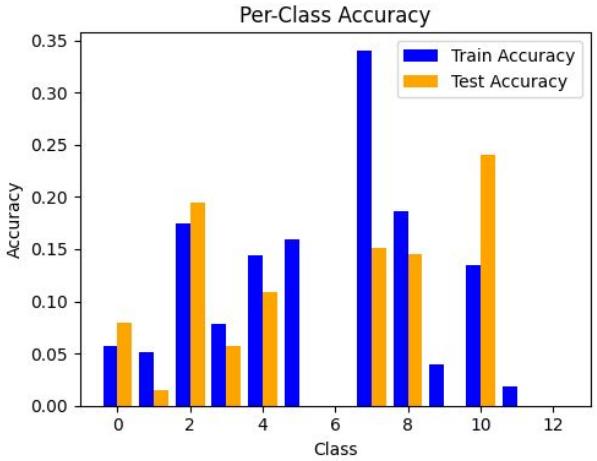
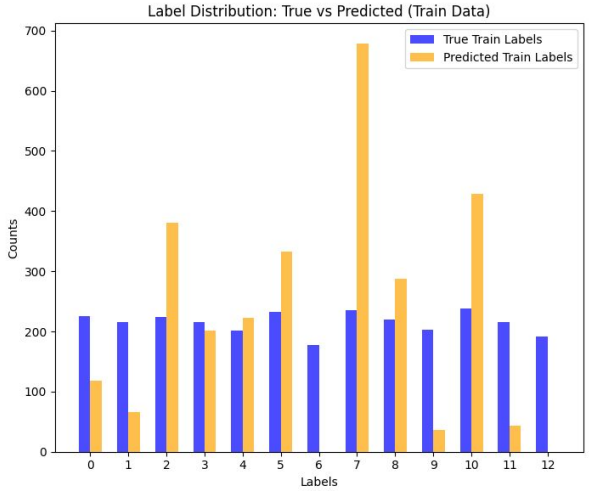
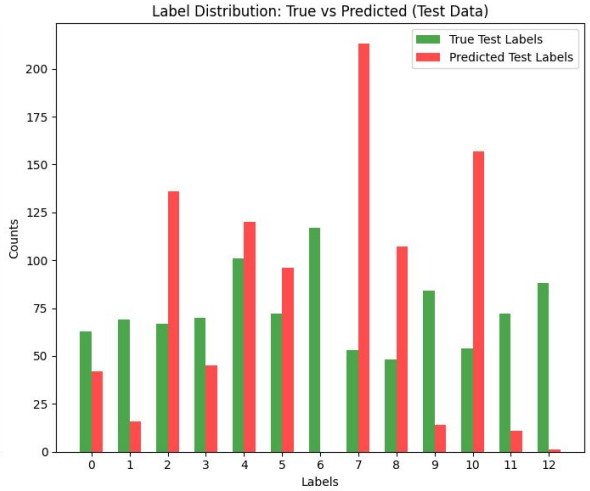








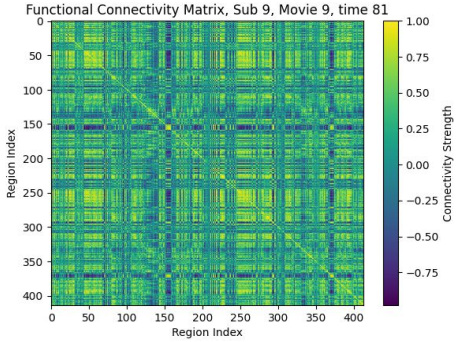
"Help! I need somebody!"

Threshold Functional Connectivity

Use Hand-Crafted Features

Time Series Kernelization

Use of Super-Subject

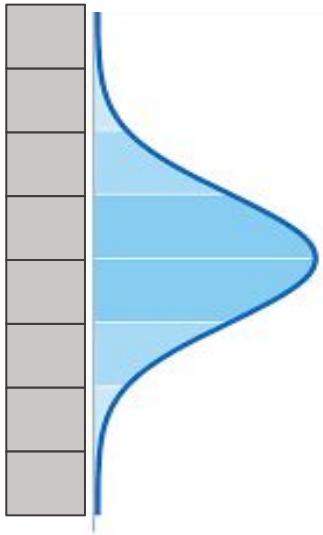


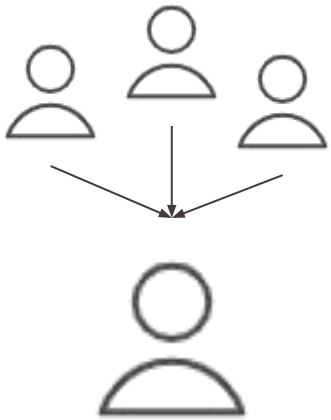
Use threshold to: Have

Sparsity, but still have

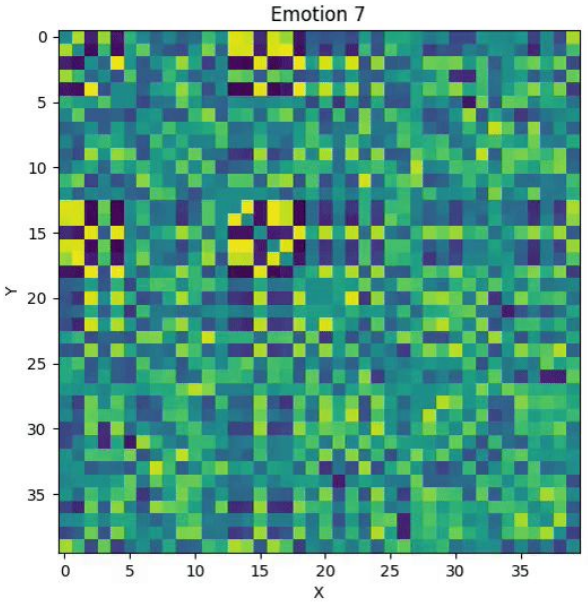
- Connected Graph

- Mean
- Std
- Autocorrelation
- Min
- Max
- ...



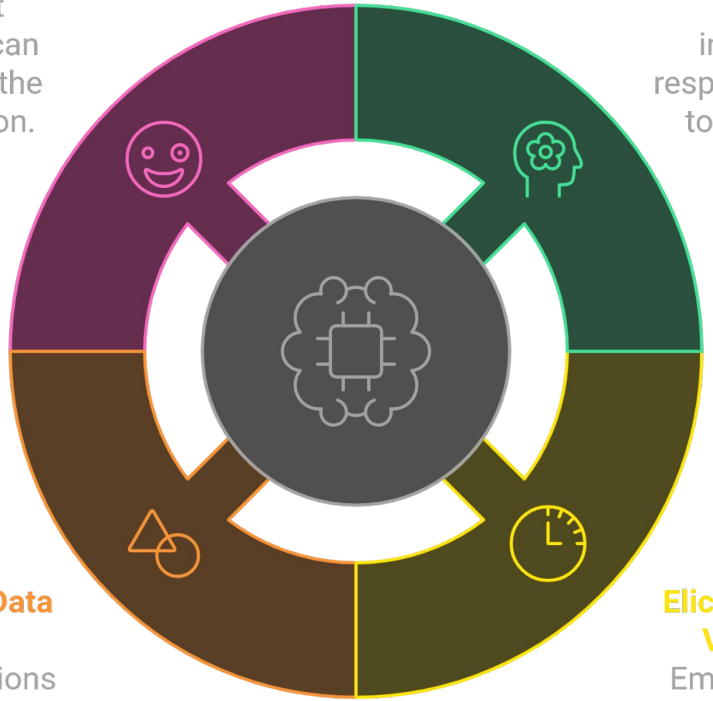


Discussion: Why not Learning



Within-Emotion Variability
Significant differences can occur within the same emotion.

Intersubject Variability
Different individuals respond uniquely to emotional stimuli.



Overlapping Data Patterns
Distinct emotions share similar data characteristics.

Elicitation Time Variability
Emotions have different times of onset and duration.

Love: Paolo and Francesca, by Dante Gabriel Rossetti

Introduction and Goals

Labels Processing

Train Test Splitting

Imputed Connectivity

Baseline: RF, KNN, FNN, GCN

GSL: GAT

State of the art: VIB

Conclusion

Conclusion

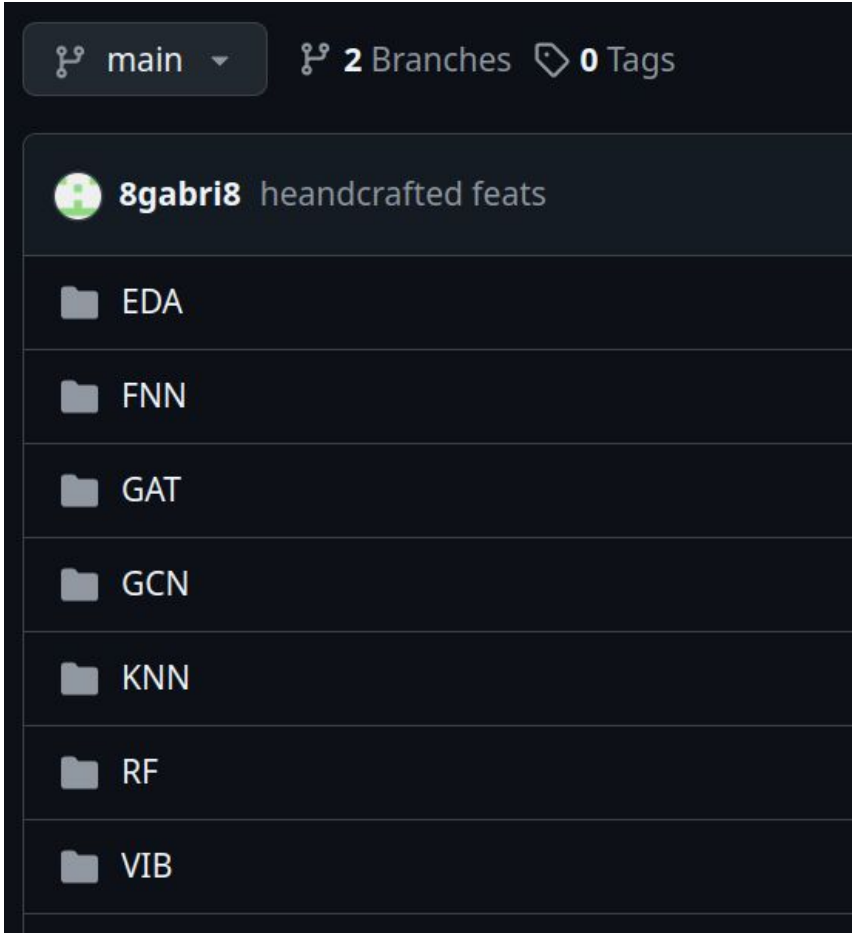
No Methods found a satisfactory solution:

- **Remained at chance level**

Still to Explore:

- **Regress Valence/Arousal/Power**
- **Use all 50 emotions**
- **Classification with multi class**
- **Unsupervised**
- **Diffusion Models**

Easy and Scalable GitHub that can be used in other Analysis



Thank you for your attention!

➔ Any questions?