Feature Reconstruction Based Channel Selection For Emotion Recognition Using EEG

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Introduction

- Emotions are natural responses to circumstances (internal and/or external events).
- Human emotions have been predicted by observing parameters like facial expression.
- There is interest in the use of Electroencephalogram (EEG)

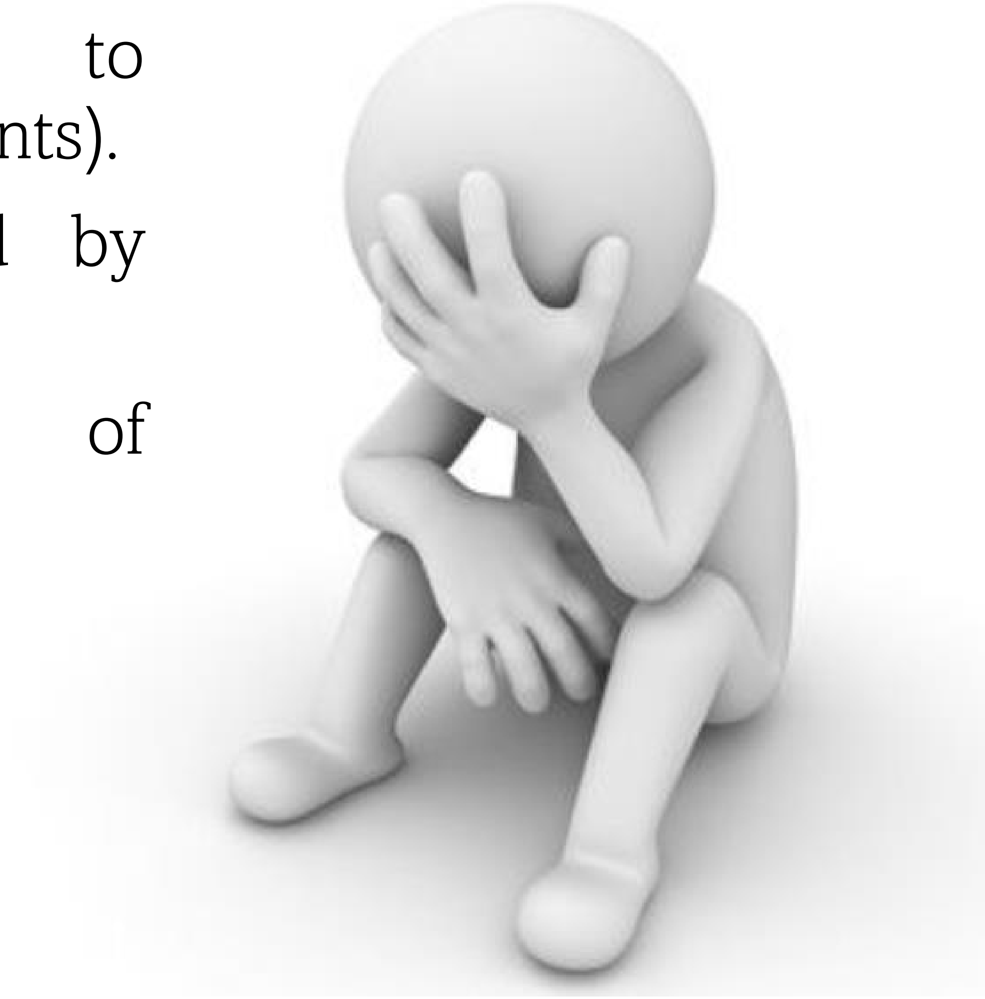


Image Credit: https://www.pinterest.co.uk/

The Problem

- Established EEG systems have up to 256 electrodes but are very expensive.
- Wearable EEG devices come in different configurations
- The question is: What is the minimum number of electrodes and where do we place them on the scalp for emotion recognition?

International 10/20 System

- Standardised method to describe EEG electrode location.
- Based on percentage of left to right or front to back distance

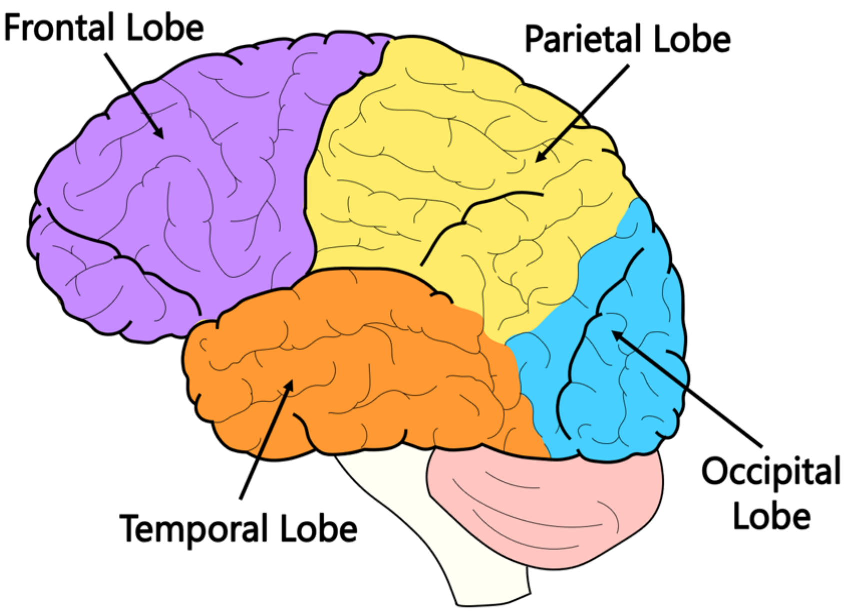
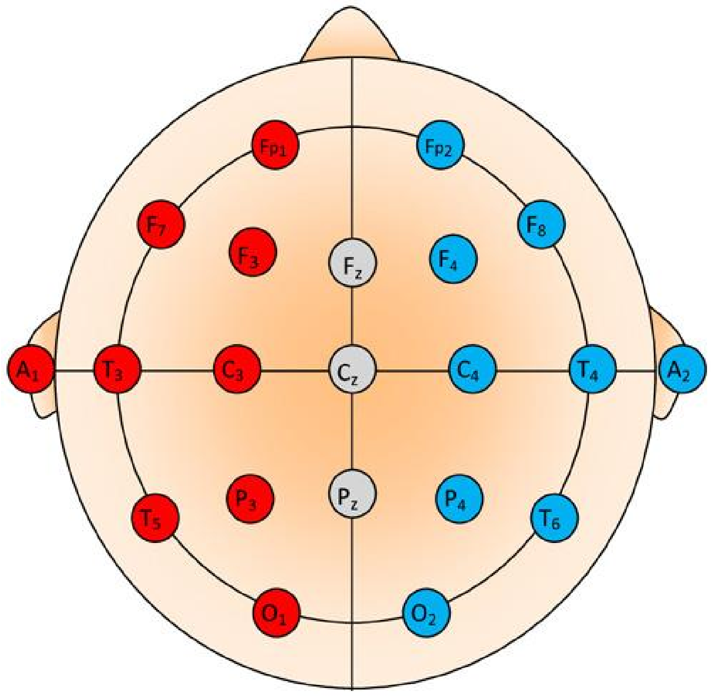


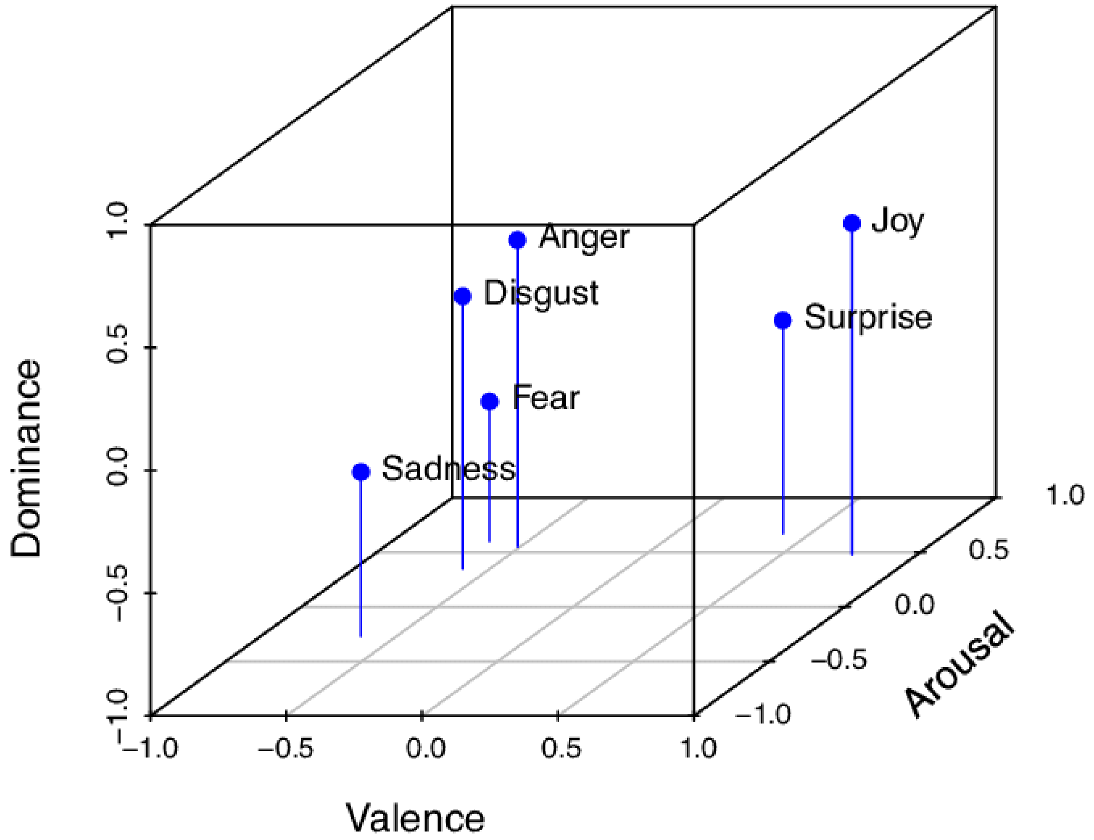
Image Credit: https://brainframe-kids.com/brain/facts-lobes.htm

- F - Frontal lobe
- T - Temporal lobe
- C - Central region
- P - Parietal lobe
- O - Occipital lobe



Data Description

- DEAP: 32 EEG channels
- DREAMER: 14 channels
- AMIGOS: 14 channels
- Self-Assessment Manikin (SAM) for self rating of emotions.

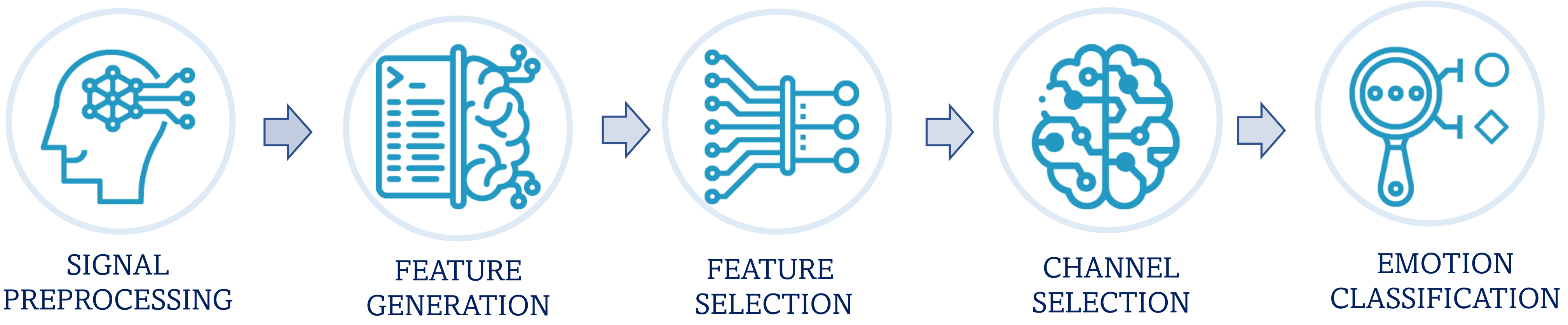


3D Representation of the SAM Scale

Image Credit: https://www.mdpi.com/2073-8994/12/1/21

Our Approach

- Goal is to identify suitable features for emotion recognition and thereafter, reconstruct the selected features using fewer channels/electrodes.
- It is a five-stage pipeline.



Preliminary Steps

Step 1

- Label binarization
- Extract final 60 secs of signal.
- Segment into 5 sec epochs.
- Channel mean subtraction

Step 2

- Full Band Signal
- EEG Band Decomposition
- Empirical Mode Decomposition
- Wavelet Decomposition

Step 3

- Fractal dimension measures
- Entropy based features
- Statistical features
- Energy… etc..

- Tested feature selection methods like ANOVA, BorutaShap, Tree Ensemble feature importance, recursive feature elimination etc.

Channel Selection Algorithm Summary

- Given output of feature selection as set of B positional features.
- To get best k out of N channels:
  1. Collect all possible channel combinations, $\mathbf{C}_{\mathbf{k}}^{\mathbf{N}}$;
  2. Calculate minimum sum of square error between each combination and corresponding features in B;
  3. REPEAT (2) for all combinations; and
  4. RETURN the combination with the least reconstruction error

Channel Selection Algorithm [1]

- Assuming we had :
  - five electrode positions - F3, T8, T7, P7, AF4
  - four features extracted from each position: power (POW), entropy (ENT), fractal dimension (FD) and zero crossing rate (ZR).
  - 2 class labels – 0, 1
- We will obtain 20 positional features and a label vector as below :

AF4_FD	AF4_ZR	LABEL
0.709	0.518	0
0.562	0.153	1
0.538	0.988	1
0.271	0.549	0

F3_POW	F3_ENT	F3_FD	F3_ZR	T8_POW	T8_ENT	T8_FD	T8_ZR	T7_POW	T7_ENT	T7_FD	T7_ZR	P7_POW	P7_ENT	P7_FD	P7_ZR	AF4_POW	AF4_ENT	AF4_FD	AF4_ZR	LABEL
0.676	0.285	0.836	0.398	0.529	0.986	0.684	0.096	0.989	0.373	0.412	0.465	0.478	0.669	0.445	0.732	0.303	0.241	0.709	0.518	0
0.385	0.467	0.833	0.858	0.287	0.157	0.146	0.351	0.737	0.986	0.898	0.491	0.156	0.552	0.459	0.589	0.818	0.685	0.563	0.153	1
0.086	0.736	0.093	0.602	0.918	0.895	0.049	0.463	0.133	0.935	0.469	0.854	0.207	0.377	0.664	0.471	0.781	0.988	0.538	0.988	1
0.759	0.732	0.478	0.053	0.937	0.547	0.851	0.332	0.541	0.131	0.555	0.037	0.763	0.908	0.601	0.347	0.179	0.085	0.271	0.549	0
0.869	0.281	0.634	0.772	0.385	0.504	0.201	0.293	0.361	0.856	0.528	0.244	0.205	0.565	0.221	0.793	0.589	0.922	0.468	0.148	0
0.893	0.253	0.403	0.727	0.698	0.006	0.408	0.501	0.301	0.009	0.779	0.979	0.349	0.482	0.573	0.801	0.929	0.908	0.606	0.168	1
0.692	0.012	0.924	0.371	0.163	0.883	0.524	0.735	0.244	0.319	0.225	0.693	0.387	0.282	0.192	0.893	0.253	0.119	0.205	0.342	0

Channel Selection Algorithm [2]

- Again, assume feature selection algorithm output as F3_POW, T8_ENT, AF4_ZR, P7_FD.
- To select the best two channels:

STEP 1: Combinations of two from five electrodes (F3, T8, T7, P7, AF4). Thus,

$$C_2^5 = \frac{5!}{2!\,(5-2)!} = 10$$

[F3, T8],	[F3, T7],	[F3, P7],	[F3, AF4],	[T8,T7],
[T8,P7],	[T8, AF4],	[T7,P7],	[T7, AF4] ,	[P7, AF4]

Channel Selection Algorithm [3]

STEP 2: For each of the combinations in step 1, we find the best substitute for each of the target features obtained after feature selection.

E.g., for candidate combination [T7, AF4] and target feature F3_POW, we compute:

$$A = \|T7\_POW - F3\_POW\|_2$$

$$B = \|AF4\_POW - F3\_POW\|_2$$

The one with a lower error is a better substitute for F3_POW

STEP 3: REPEAT step 2 to get substitutes for T8_ENT, AF4_ZR and P7_FD

Channel Selection Algorithm [4]

STEP 4: REPEAT steps 2 and 3 for all combinations to get substitutes such as:

COMBINATION	F3_POW	T8_ENT	AF4_ZR	P7_FD
[F3, T8]	F3_POW	T8_ENT	T8_ZR	F3_FD
[F3, T7]	-	-	-	-
[F3, P7]	-	-	-	-
[F3, AF4]	F3_POW	AF4_ENT	AF4_ZR	AF4_FD
[T8,T7]	-	-	-	-
[T8,P7]	-	-	-	-
[T8, AF4]	-	-	-	-
[T7,P7]	-	-	-	-
[T7, AF4]	T7_POW	AF4_ENT	T7_ZR	AF4_FD
[P7, AF4]	AF4_POW	P7_ENT	AF4_ZR	AF4_FD

Channel Selection Algorithm [5]

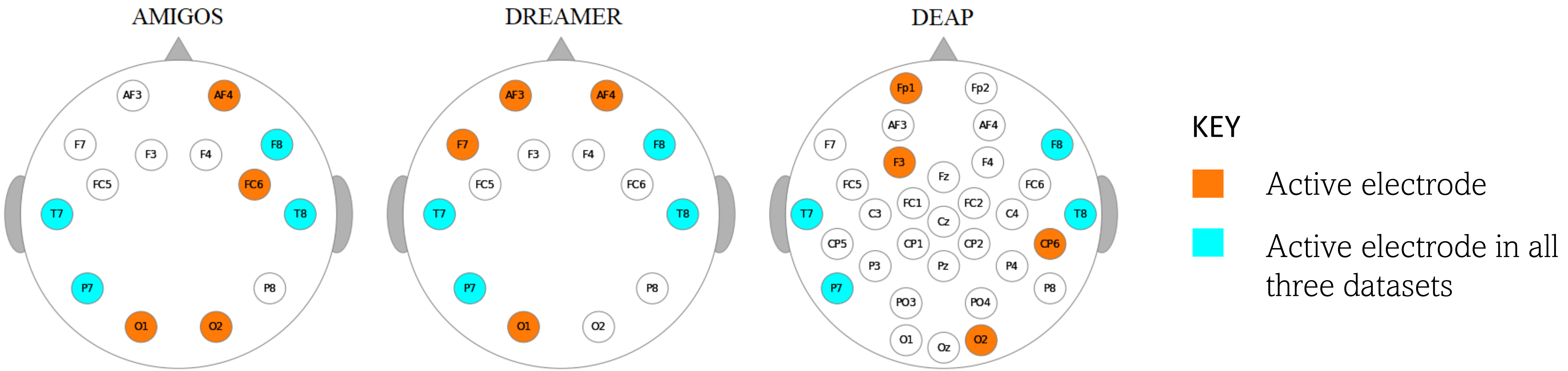
STEP 5: Calculate reconstruction error between channel combinations and the target features as the total mean squared errors from all substitute features to the targets.

COMBINATION	F3_POW	T8_ENT	AF4_ZR	P7_FD	SUM
[F3, T8]	0.000	0.009	0.002	0.009	0.0246
[F3, T7]	0.000	0.011	0.008	0.006	0.0251
[F3, P7]	0.000	0.002	0.003	0.007	0.0132
[F3, AF4]	0.002	0.001	0.005	0.002	0.0099
[T8,T7]	0.006	0.004	0.001	0.002	0.0127
[T8,P7]	0.001	0.009	0.003	0.002	0.0116
[T8, AF4]	0.011	0.009	0.008	0.005	0.0334
[T7,P7]	0.006	0.001	0.003	0.004	0.0138
[T7, AF4]	0.002	0.009	0.007	0.004	0.0217
[P7, AF4]	0.008	0.004	0.003	0.006	0.0216

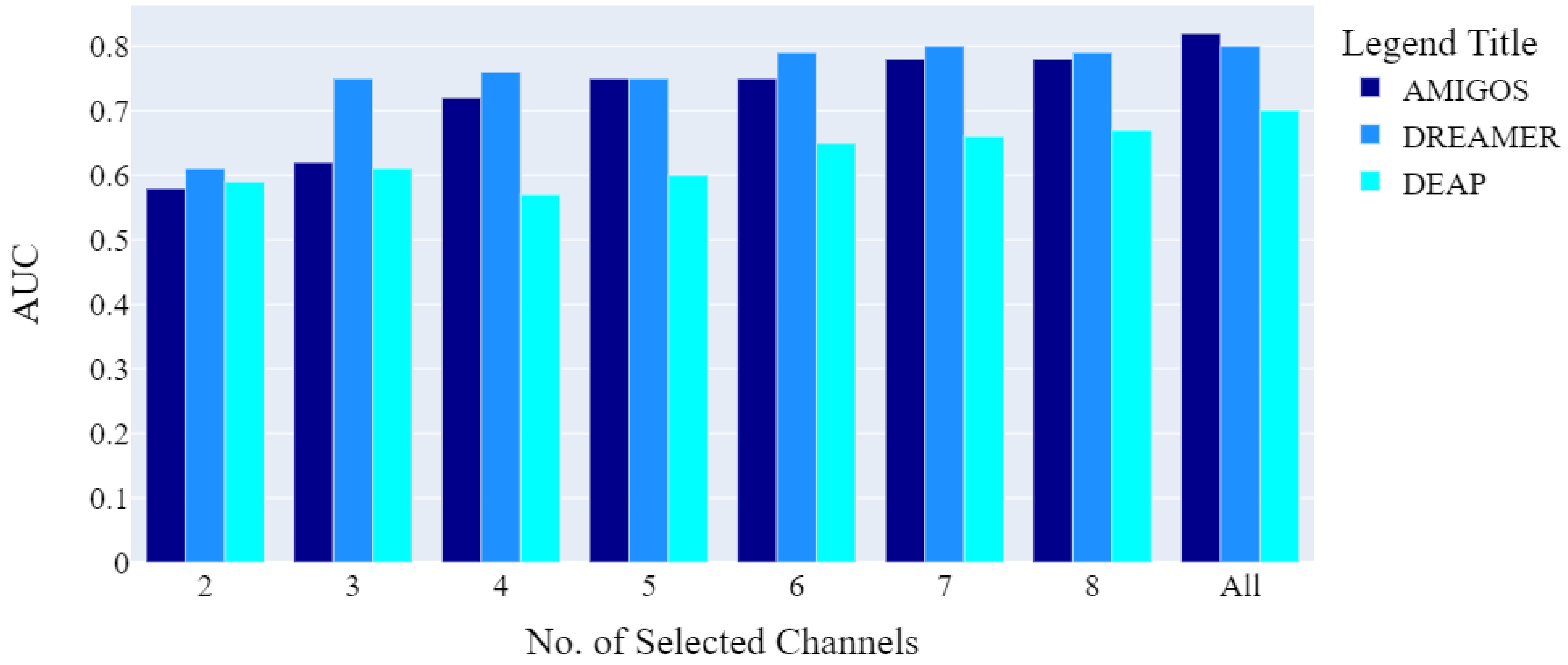
Best substitute features F3_POW, AF4_ENT, F3_ZR and AF4_FD

Results [1]

NUMBER OF CHANNELS	AMIGOS	DREAMER	DEAP
2	['FC6', 'O1']	['AF4', 'P7']	['CP6', 'T8']
3	['FC6', 'O1', 'P7']	['AF4', 'P7', 'T8']	['CP6', 'F3', 'T8']
4	['FC6', 'O1', 'P7', 'T8']	['AF4', 'F8', 'P7', 'T8']	['F3', 'Fp1', 'P7', 'T8']
5	['AF4', 'FC6', 'O1', 'P7', 'T8']	['AF4', 'F7', 'F8', 'P7', 'T8']	['F3', 'Fp1', 'O2', 'P7', 'T8']
6	['AF4', 'FC6', 'O1', 'P7', 'T7', 'T8']	['AF3', 'AF4', 'F7', 'F8', 'P7', 'T8']	['F3', 'Fp1', 'O2', 'P7', 'T7', 'T8']
7	['AF4', 'F8', 'FC6', 'O1', 'P7', 'T7', 'T8']	['AF4', 'F7', 'F8', 'FC6', 'O1', 'P7', 'T8']	['F3', 'F8', 'Fp1', 'O2', 'P7', 'T7', 'T8']
8	['AF4', 'F8', 'FC6', 'O1', 'O2', 'P7', 'T7', 'T8']	['AF3', 'AF4', 'F7', 'F8', 'O1', 'P7', 'T7', 'T8']	['CP6', 'F3', 'F8', 'Fp1', 'O2', 'P7', 'T7', 'T8']

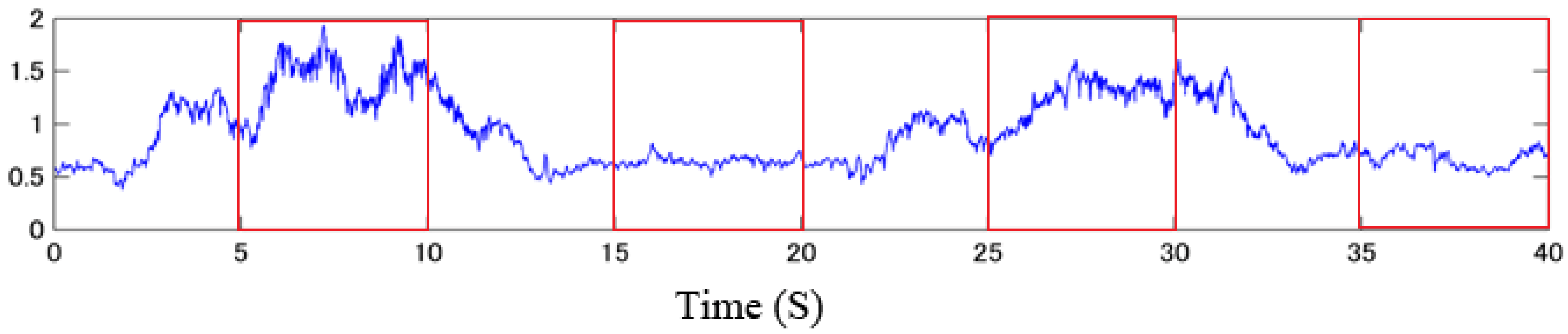


Results [2]



AUC
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2
3
4
5
6
7
8
All
No. of Selected Channels
Legend Title
AMIGOS
DREAMER
DEAP

Weaknesses and Future Work



- Time segmentation of the signal may not be ideal
- L2 norm tends to penalize outliers
- Next step : Graph Convolution Network models

Thank You!

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