01/8/25
Friday

Neuroinformatics

→ **Syllabus and Grading Scheme** (UnGrading)

* For some classes we are required to watch lecture videos (recorded in prev sem) & submit the questions & comments about the videos & reading material 12hrs before class

* come up with personalized goals that are measurable.

* List of Sample Topics & Activities :-

1) Intro & understanding the origin of data.
2) Decomposing the signals for further analysis
3) Neuronal synchronization
4) Non parametric statistics
5) Advanced & special topics.

* Graded Course Activities:-

- Complete assigned readings & feedback on videos, Highlights of TB pdf → live document = 20%
- Take home prblm sets (Team-2) = 25%
- Quiz-1, Quiz-2, Mini quizzes = 15%
- class participation = 10%
- Final project ⇒ 3 presentations = 20%
- Final Report & peer reviewing = 10%

100%

* Submit a reflection form for each activity above that will help you/me grade myself. (At the end of each month) ⇒ prof & TA will share Templates.

* Minimum Requirements for this course :

1) class participation
2) Group project ← presentations, Final report
3) Take Home prblm sets

→ Do Just these 3 ! with the goals you assigned yourself → C
→ complete all components & do more like add additional components & exceptionally well in atleast 2 of them, ⇒ A Grade,

By the End of the course, the Basic goal everyone should met,

- Given some nueral data & able to do Exploratory initial analyses & come up with research Q's that can be answered using SP & SM methods
- Performing Time freq analyses by justifying the methods used
  - How & why specific filtering scheme?
  - Constraints & parameters
  - windows for filtering, task epochs for analyses.
- Should be able to apply appropriate statistical techniques & corrections to able proper interpretation of the resulting patterns.

* For project → Datasets already mentioned in the syllabus pdf
  - → Choose an EEG or intracranial EEG dataset
  - → MEG or Local field Potential data (Also fine)
  - → fMRI ⇒ limited & specific techniques (will not be a part of course) (Avoid ✗)

Remember !!

Not a ML Course ...
So, Classification Analysis or Deep Learning Methods donot count ~~towards Project~~

☆ Only Signal processing & statistical Methods (Taught in class (or) some Adv versions of such methods as applied to our datasets will count towards project ✓

- You can also pick a neuroscience paper to replicate their analyses.

Follow Rubric for our project (given by Prof)

Project

① Recorded proposal of project

② Mid sem In class Presentations

③ Final Presentations in class

④ Report
  - Intro
  - Methods
  - Results
  - Conclusion & Discussion
  - Formatting, citations
  - Ref

Paper publishing?

* Letter Grade Assignment
  - via SMART goals doc
  - Reflection doc
  - Measurable & verifiable activities
    - To show you completed readings, assignments, projects.
  - Final Discussion with prof

01/08/25

NeuroInformatics Introduction

Lecture 0

Analyzing Neural Time series

EEG Electroencephalogram

Are voltage time series recorded from the brain. they show oscillations (rhythms) & transient events

-> Time domain :- shows how signal changes over time
-> Freq domain :- shows how power is distributed across frequencies

-> EEG measures tiny voltage diff b/w electrodes placed on the scalp (or inside the brain for intracranial EEG)

units :- μV

Sleep stage Traces :-

-> wake/alert => low amplitude, High frequency (fast) activity

S1: light sleep :- More theta activity (4-7 Hz) slightly higher amplitude than wake

S2: sleep spindles: ~11-15Hz bursts and K-complexes (large slow deflections)

-> Brief rhythmic bursts

S3: Deep sleep: slow wave activity (0.5-2Hz), high amplitude & slow oscillations

-> IEEG : electrodes placed on or in brain tissue - much higher spatial resolution & SNR

=> So local oscillations & High freq activity (>80Hz) are easier to see

Trend	Seasonal	Residual
	Regular repeating cycles	Remaining Irregular Noise

Detecting patterns in EEG ≈ Detecting patterns in other time series like power consumption

Theta (4-8 Hz) slower waves => drowsiness.
beta (13-30Hz) faster waves => alertness

What do we seek to understand from these neural recordings?

connect Brain Activity Patterns → came from EEG or IEEG

→ Behavior & cognition

→ Time locked to stimulus

→ Time locked to response

Encoding phase → Distraction phase → Retrieval phase

→ Neural Data Recording Methods:

i) fMRI - functional Magnetic Resonance Imaging

- Measures brain activity indirectly by tracking blood flow changes

BOLD fMRI
↓
Blood oxygen level Dependent

coupling b/w

Neuronal Activity ⇄ Hemodynamics → dynamics of Blood flow

- How it works:

- Neurovascular Coupling: when neurons fire in a brain region, they use more O_2. The body responds by sending extra oxygenated blood there.

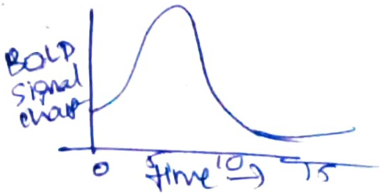
Oxygenated Hemoglobin
↓
Non magnetic (Dia ")

De oxygenated Hemoglobin
↓
Slightly magnetic (Para ")

- MRI scanners detect small diff in magnetic properties b/w oxygenated and Deoxygenated blood.
- The BOLD signal increases in areas receiving more oxygenated blood after neuronal activation.

$\boxed{\text{Slow !!}}$ → Because MRI scanner doesn't directly measure neural firing - it measures slower hemodynamic response.

HRF & Hemodynamic Response fn



Delay limits Temporal resolution

EEG & MEG → can track millisec changes

Pros: High spatial res, non-invasive

Cons: Low Temporal res, [6-8sec lag] Motion sensitive, /noise

→ MEG - Magnetoencephalography
- records magnetic field created by electric fields in brain
- used for understanding neural basis of behavior & cognition & also localization purposes prior to surgery

Basis of the signal:

- Source Neurons:
  i) Large pyramidal neurons in layer V of cortex
  ii) Arranged in ||el, oriented ⊥er to surface
  iii) Fire synchronously
- Dipolar currents ⇒ create tiny magnetic field
- 10k - 50k active neurons required for detectable signal
- MEG magnetic field not distorted by conductive properties of scalp / head.
- only <1% of cell populations are perfectly radial ⇒ on top of gyri
- Relative field strengths:
  i) signal is Tiny
  ii) Interference from electrical equipment
  iii) requires magnetically shield rooms & supersensitive magnetometers.

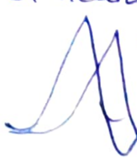
∴ sp is critical to filter out noise from environmental sources

- Pros: High temporal res, High spatial res, No distortion of Magnetic fields by skull / scalp
- Cons: Needs to be highly shielded, measuring really small magnetic fields generated by neuronal currents

→ EEG - Electroencephalography
- scalp recording of electrical activity of neurons (μV)

Basis of the signal:

i) PSP's can be excitatory or Inhibitory
ii) MEG / EEG reflects summation of synchronous PSP's
iii) Large pyramidal neurons in cortex layer.



Action potential
⇓
Biphasic
• donot summate

Post synaptic Potential (PSP

Distortion by Skull / scalp
Temporal res ~1ms
Spatial res ~1cm

Dipole orientation: Tangential & radial

∴ EEG/MEG - Adv & Dis Adv (Read from Lec's slides)

→ Forward & Inverse Problem:

If you know source of neuronal activity (location, orientation & curr density)

⇓

Calculate EEG or MEG signal

You start with EEG/MEG sensor data & try to work backwards to figure out.

"Use frwd models for Inverse prblm!"

→ Intracranial EEG: Electrodes are placed directly on surface of the brain (beneath the skull)

- Higher spatial source accuracy than scalp EEG

→ ElectroCorticography: (ECoG)

↳ Type of iEEG with electrodes placed on the cortical surface

↳ Epilepsy surgery planning
↳ Functional mapping of brain areas by stimulating regions
} used in

★ ↳ High res than scalp EEG

→ Local Field Potentials: (LPF's)

- Records electrical potentials from small populations of neurons
- signals are typically filtered to below 500Hz
- A measure of sub threshold neuronal activity

Single Neuron firing

Data Analysis overview