

Time Series

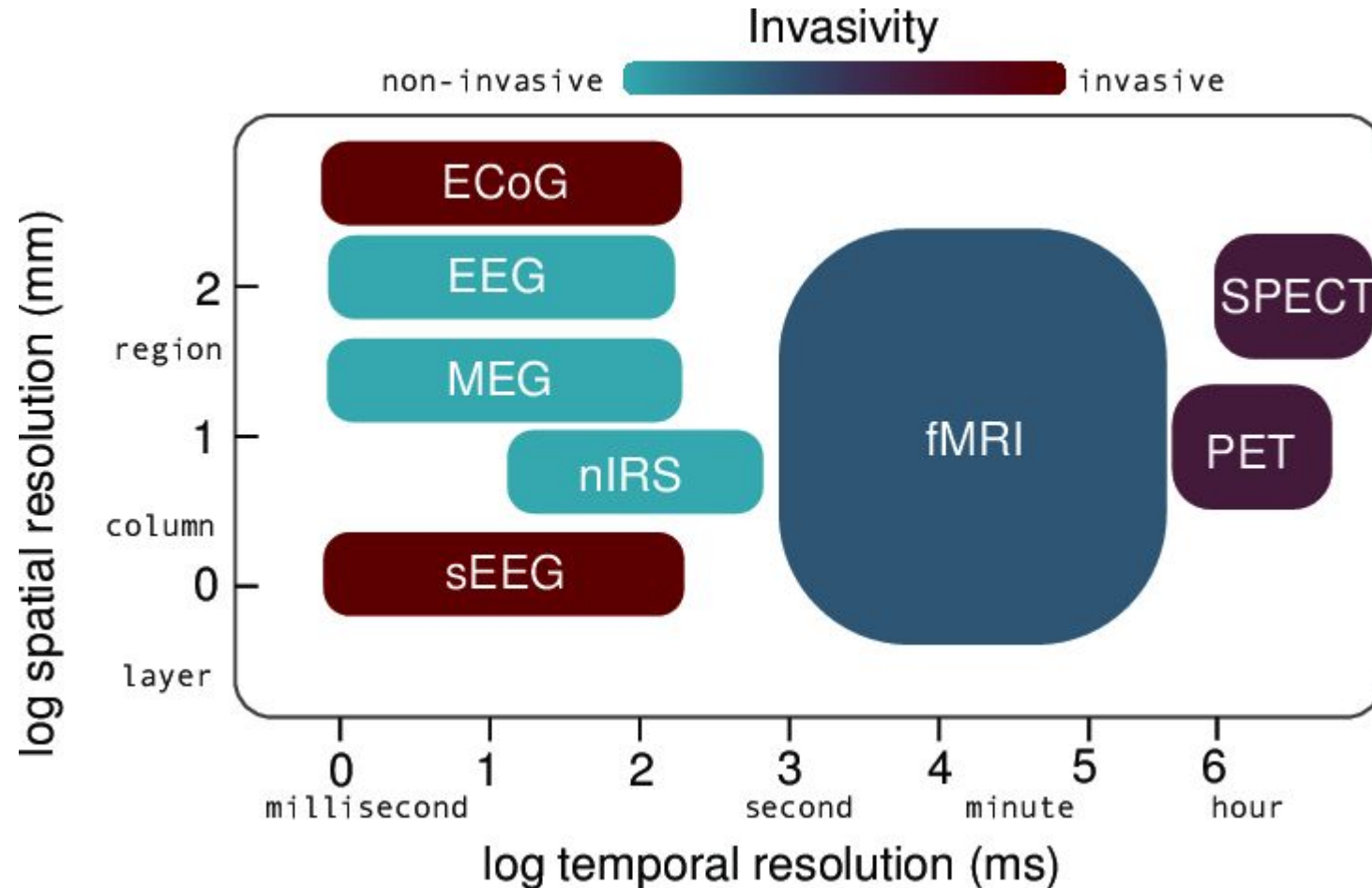
Basics and processing

Advanced Programming for Neuroscience Students

What we will learn:

- What is a time series?
- Components of a time series
- Processing time series
- Analysis of time series
- Example of time series data and how to process it

Spatial and temporal resolution

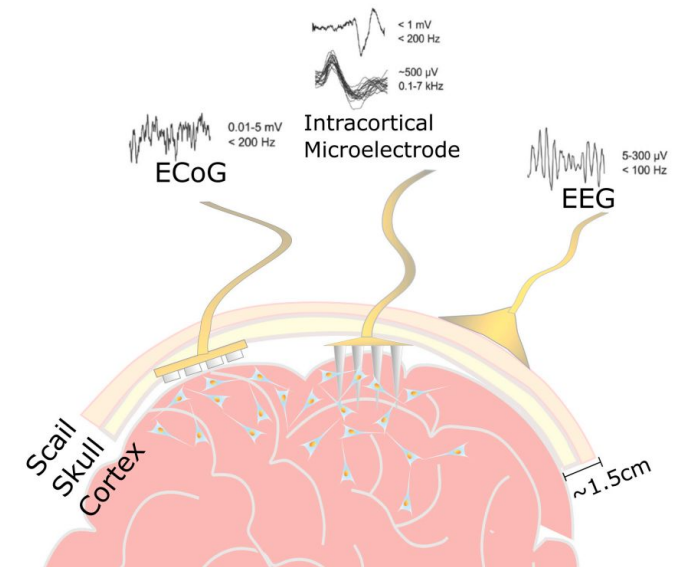
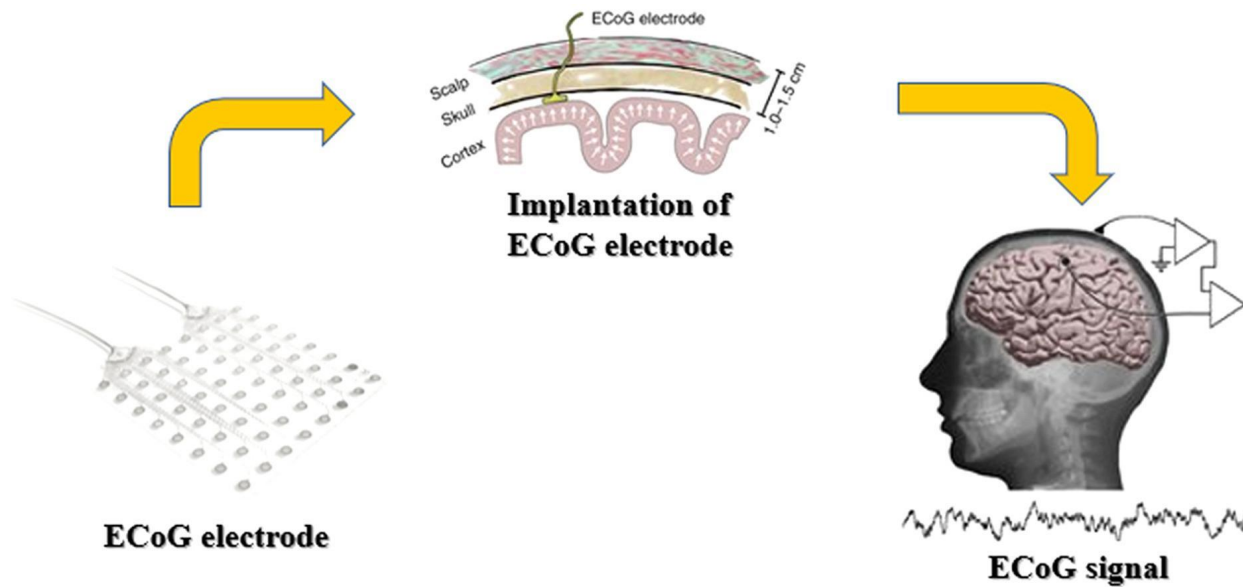


Our example time series - ECOG

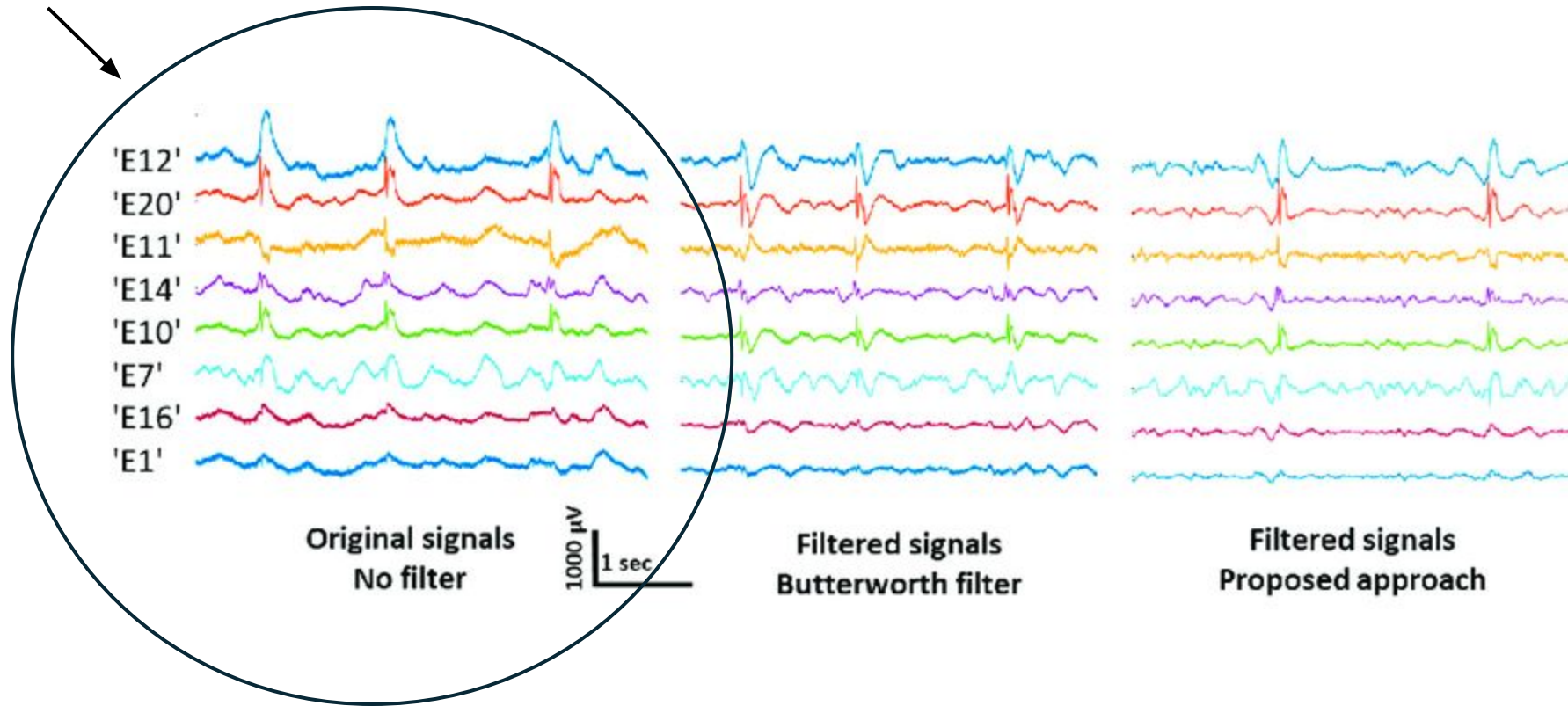
- We will explain the concept of time series through ECOG examples
- What is ECOG?

I will show you on the next slide...

ECOG records neural signals over time



A raw time series signal



Components of a time series

- Trend
- Seasonality
- Residuals (irregularities)

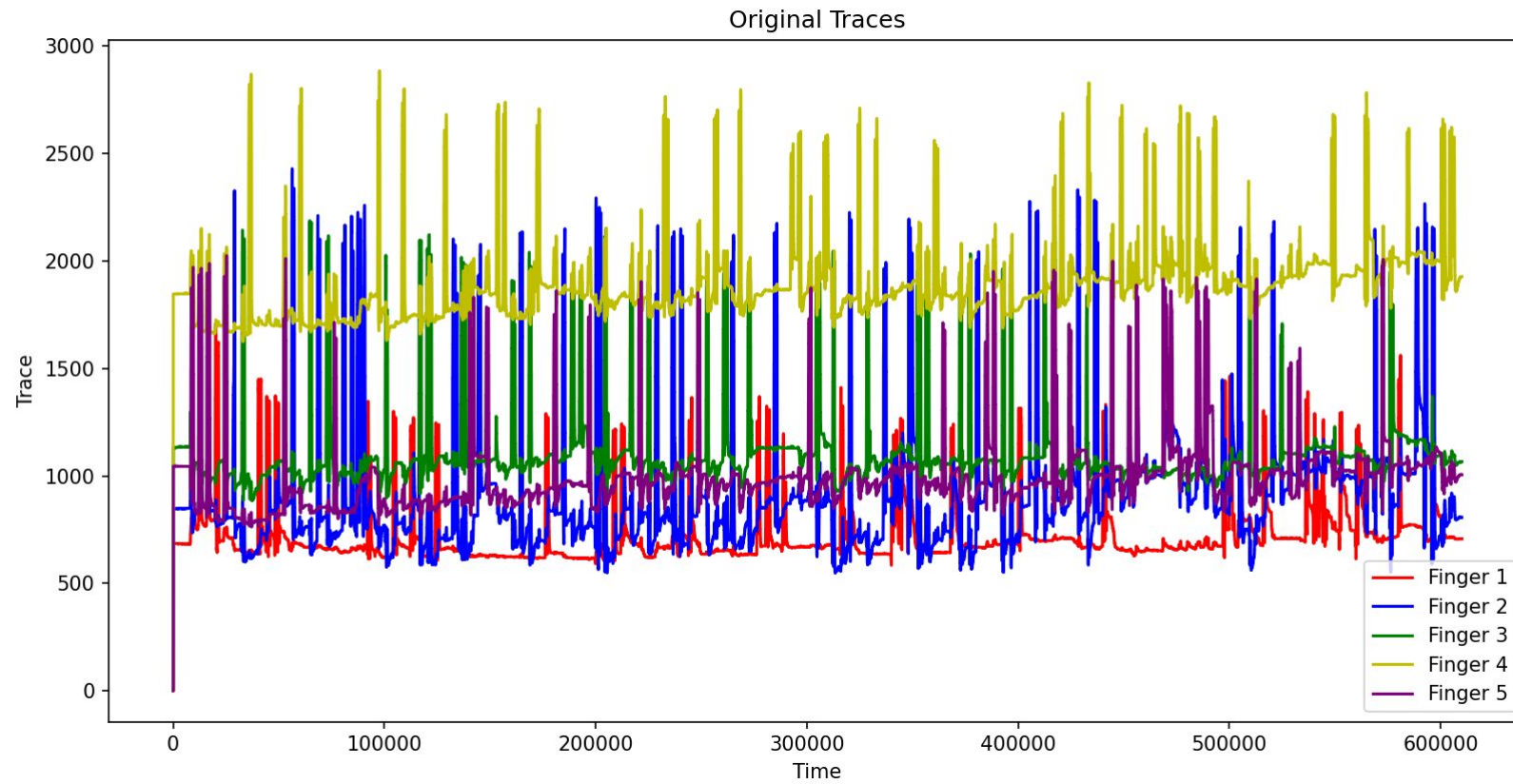
You spoke about trend and seasonality in the lecture.

We are going to focus on noise.

Example using real data

- We are going to look at finger data and ECOG signals.
- Experiment set up:
- There are many trials for each event – each event consists of moving a finger after a stimulus appeared on the screen

Finger data



Noise

- What are some potential causes of noise to a signal?
 - Movements
 - Other organs functioning
 - Technology noise
- Why is it important to remove noise?

Noise removal

There are a few ways to remove noise – we will mention the ones we use for this data.

- Filtering – we remove noise and smooth the signal using filters and windows (we also remove outliers)
- We upsample or downsample in order to coordinate between different sampling rates
 - **What is sampling rate?** How often we “check in” with the signal – how often we record it.
- Normalization/Standardization – to compare across time series signals, we need to make sure they are on the same scale

Sampling rate in this data

- Sampling rate of ECOG data – 1000 Hz (1 sample every millisecond)
- Sampling rate of sensing finger movement – 25 Hz. In order to match the sampling rates – each finger movement is written 40 times – same one value on 40 rows - $40 * 25 = 1000$
- Why was this done?

So that the indices math up between the finger data and the brain data.

Let's think about the data

- How would you approach this data?
- What questions can you ask about this data and what insights can the time series data provide?



Our task – find the start of every finger movement

But first...


```
import numpy as np
import matplotlib.pyplot as plt
import scipy.io

def find_finger_events(tr):
    # x = 1:80, width of smoothing window
    x = np.arange(1, 81)

    # Gaussian smoothing window
    gs = np.exp(-((x - 40)**2) / 160)

    # Normalize the window sum to 1 to keep the same values of the smoothed signal
    gs_norm = gs / np.sum(gs)

    # Convolve gaussian & behavioral trace
    tra = np.convolve(tr, gs_norm, mode='same')
```

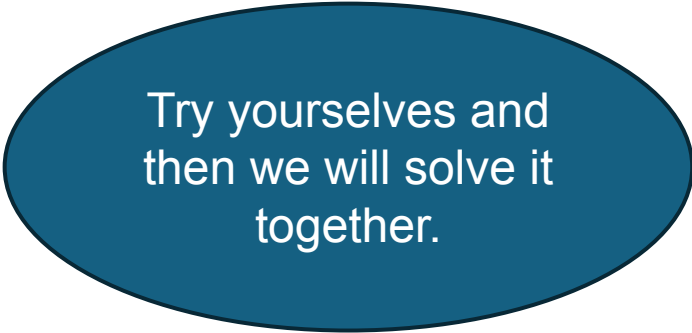


What are we doing here?

- We apply a **Gaussian function** (a bell-shaped curve) to the data in a way that averages nearby values in a weighted manner, with more importance (weight) given to points closer to the target point.
- This results in a smooth curve where noise is reduced, and the underlying trend becomes clearer

The data

- You are given the following data:
 - Finger flex data – with 5 columns and a bunch of rows. Each column belongs to a different finger that was moved during the study
 - Figure out how you can find the start of when the finger moved?
 - Hint: It is easy to find the maximum movement of a finger – how would that look in a signal?



Try yourselves and
then we will solve it
together.

Start of event

```
# Find inversion points (maximum displacement)
thresh = np.mean(tra) + np.std(tra)

a1 = tra > thresh
a2_tra = np.concatenate([tra[1:], [0]])
a3_tra = np.concatenate([0], tra[:-1])
a2 = (tra - a2_tra) > 0
a3 = (tra - a3_tra) > 0

a = np.where(a1 & a2 & a3)[0]

# Find local minima points
b2 = np.diff(np.concatenate([0], tra)) < 0
b3 = np.diff(np.concatenate(tra, [0])) < 0
```

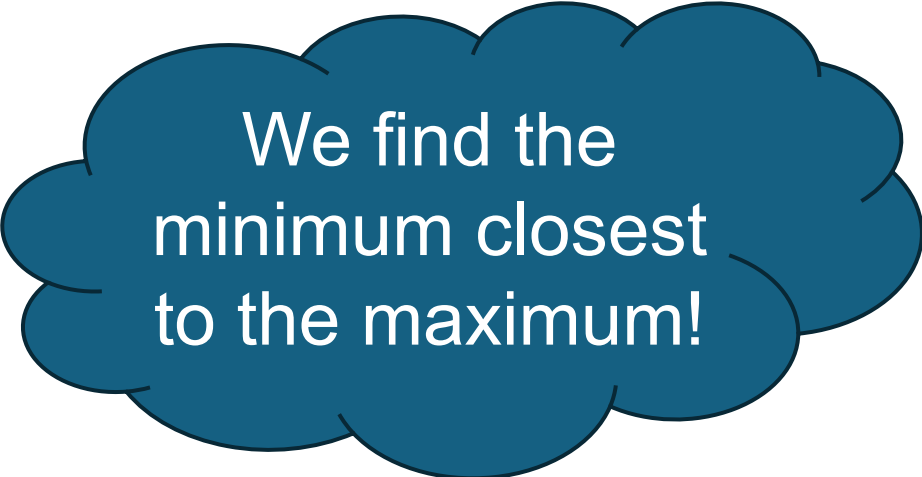
What is happening in this portion of the code?

We find the maximum points – where the finger is at the height of movement

There are MANY ways to do this

How do we find the start of the event?

```
b = np.zeros_like(a)
for i in range(len(a)):
    b[i] = closest_min[closest_min < a[i]].max() if np.any(closest_min < a[i]) else 0
```



We find the minimum closest to the maximum!

Aggregate events into one file

```
mat_file = r'C:\Users\user\Downloads\fingerflex\jp\jp_fingerflex.mat' # Replace with the actual path to your .mat file
# mat_file = r'C:\Users\user\Downloads\p1_fingerflex.mat' # Replace with the actual path to your .mat file

data = scipy.io.loadmat(mat_file)

flex_data = data['flex']

# Identify movements for each finger
st_pts, inv_pts = find_finger_events(flex_data[:, 0])
all_inv_pts = np.column_stack([st_pts, inv_pts, np.ones(len(inv_pts)).astype(int)])

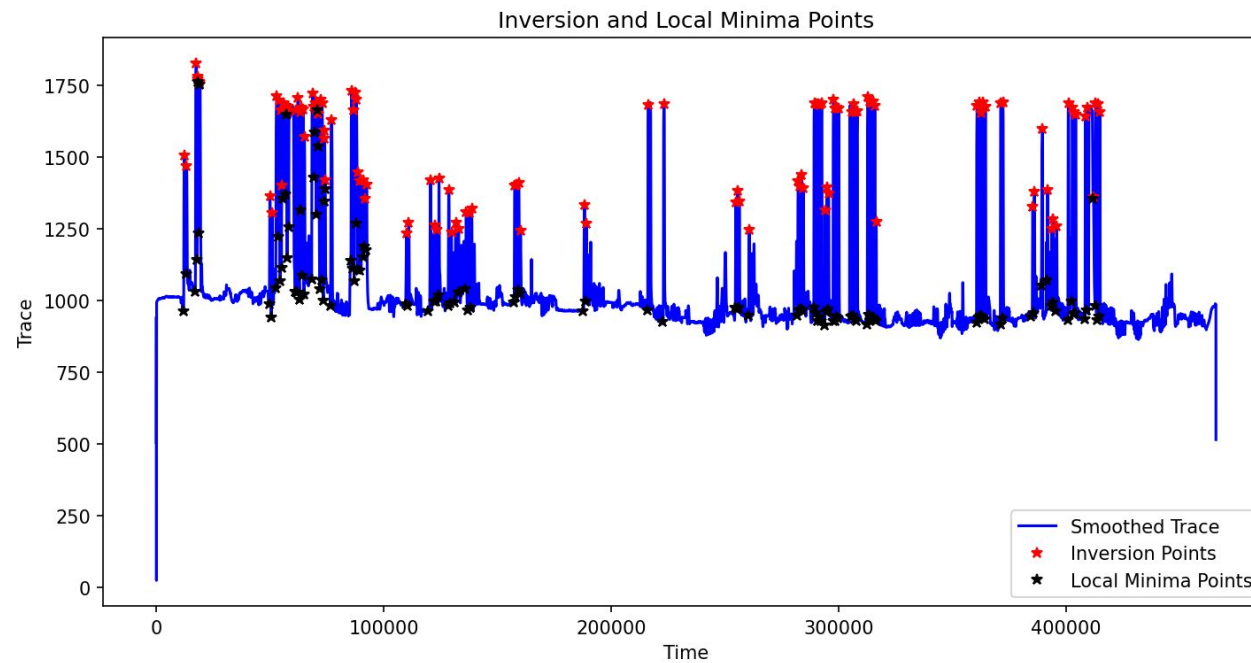
for i in range(1, 5):
    print("Calculating movement event times...")
    st_pts, inv_pts = find_finger_events(flex_data[:, i])
    all_inv_pts = np.vstack([all_inv_pts, np.column_stack([st_pts, inv_pts, (np.ones(len(inv_pts))*(i+1))])])

all_inv_pts = all_inv_pts[all_inv_pts[:, 0].argsort()]
np.savetxt(r'C:\Users\user\OneDrive - Bar-Ilan University - Students\Documents\advanced_programming_course\time_series\events_file_ordered.csv', all_inv_pts.astype(int), delimiter=',')
```

Show example of output

Start of movement	Inversion point – high	Number of event (finger)
<pre data-bbox="904 571 1643 1099">[[23901 24220 1] [24854 25219 1] [25697 26094 1] ... [397919 398360 5] [401497 401900 5] [401959 402142 5]]</pre>		

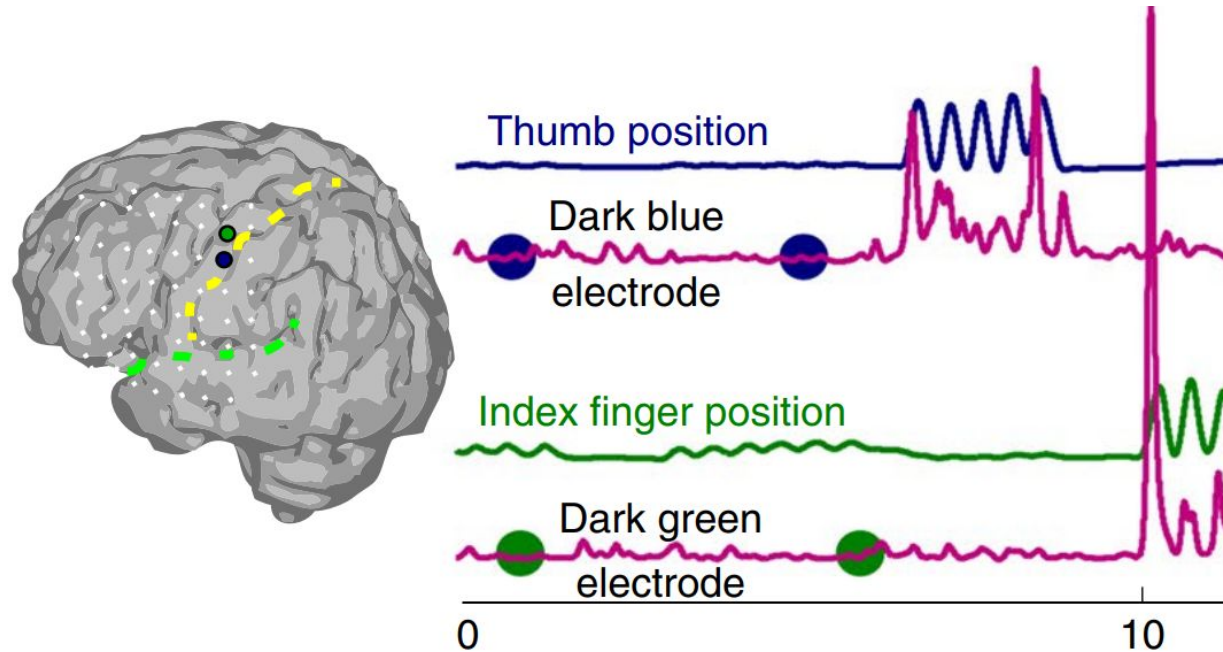
A single finger example



We have finger data and brain data...

What do we want to find out?

What can be an interesting question to ask about this data?



How does brain activity correlate to finger movement?

Go find it!

Introducing MiniProject2

- We are going to combine the finger data with the brain data
- How can we do this in a meaningful way?
- What are the steps?
- ERP!

An ERP is an Event Related Potential. A certain event that occurred that caused a brain response.

What is our event?

How can we find the brain response?