THE AMERICAN UNIVERSITY IN CAIRO

Fall 2023

CSCE 363/3611 - Digital Signal Processing

Spike Sorting

Seif Eldawlatly

Neural Engineering

- Neural Engineering is a field of research that focuses on engineering methods to investigate the function of the central and peripheral nervous system and manipulate its behavior

- Neural Interfaces are systems that can help restore sensory function, communication, and control to impaired humans

- The main principle is that disabled people would have their brains or parts of their brains fully functional

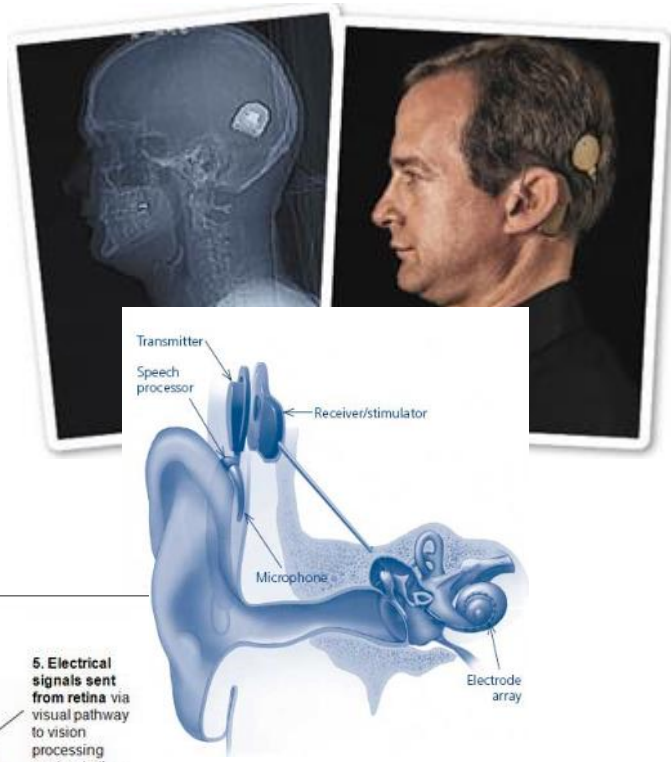
- Neural Interfaces make use of functional parts to restore a lost function

- Objectives of Neural Engineering:
  1- Understand Brain Function
  2- Provide Therapeutic, Assistive and Augmentative Technology

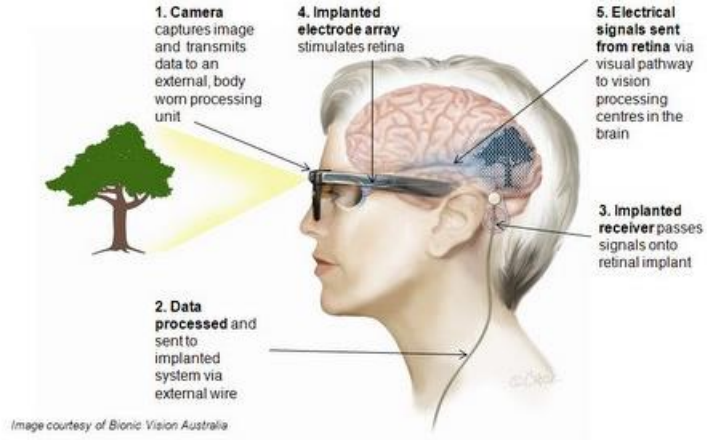
Neural Engineering

- Examples of Neural Interfaces:

Motor Brain-Machine Interface



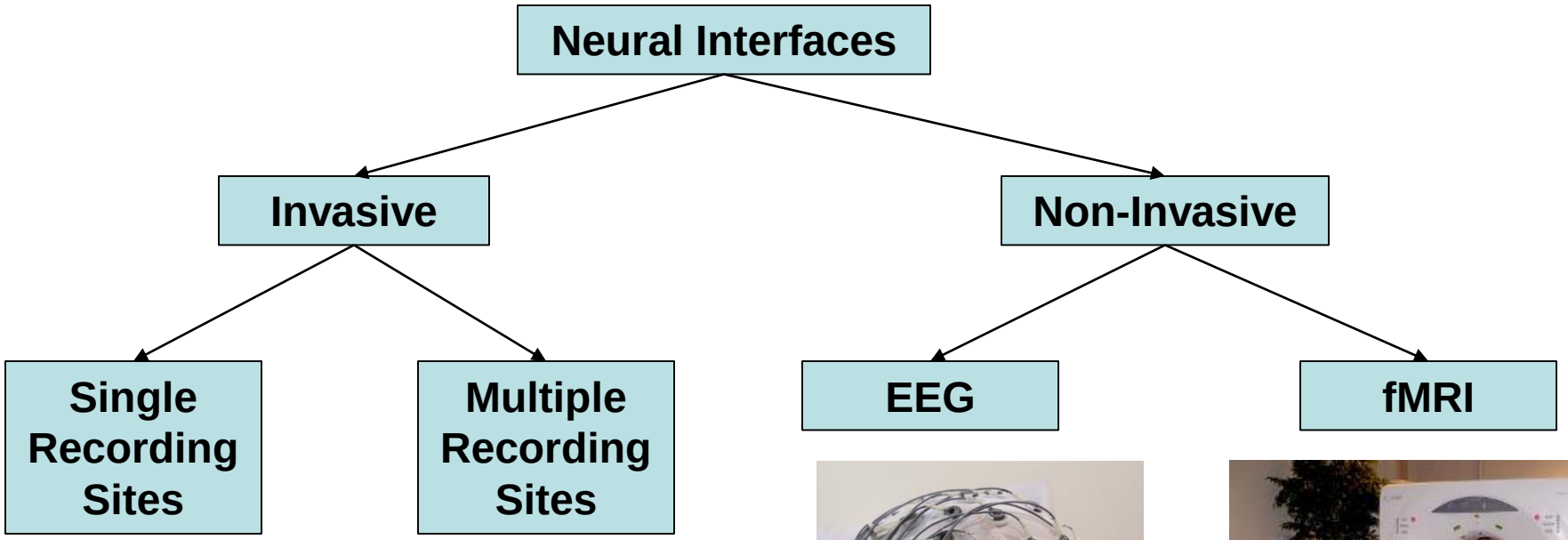
Cochlear Implant

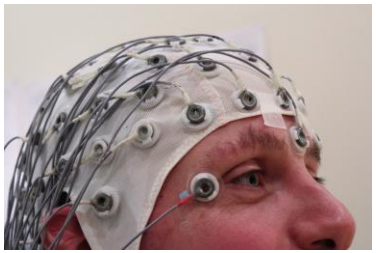


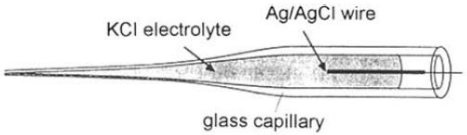
Visual Prosthesis

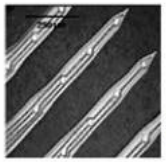
Neural Engineering

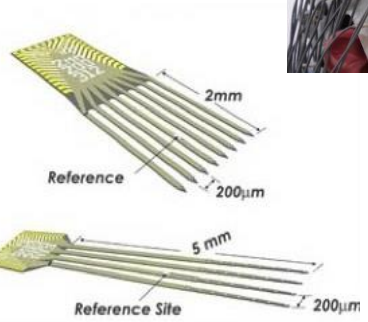
- Types of Neural Interfaces





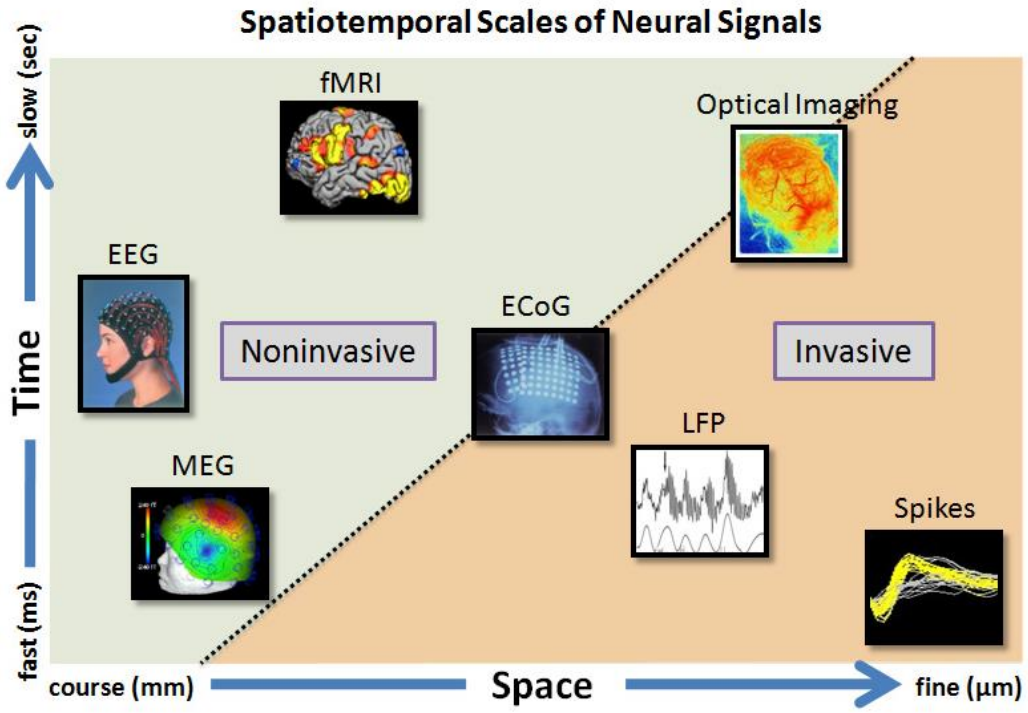


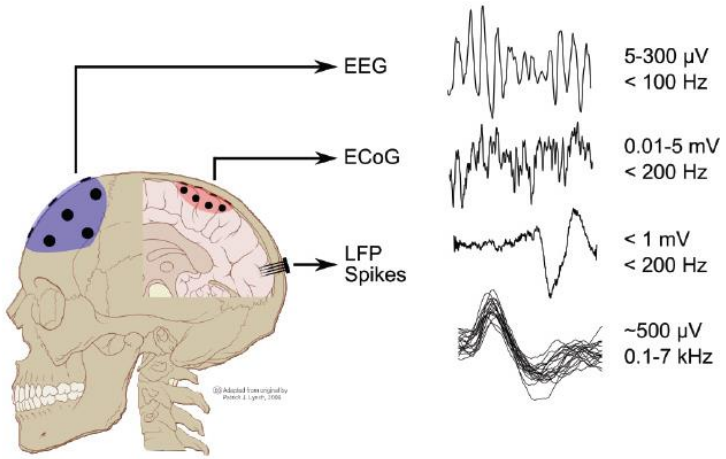




Neural Engineering

- Recorded Signals

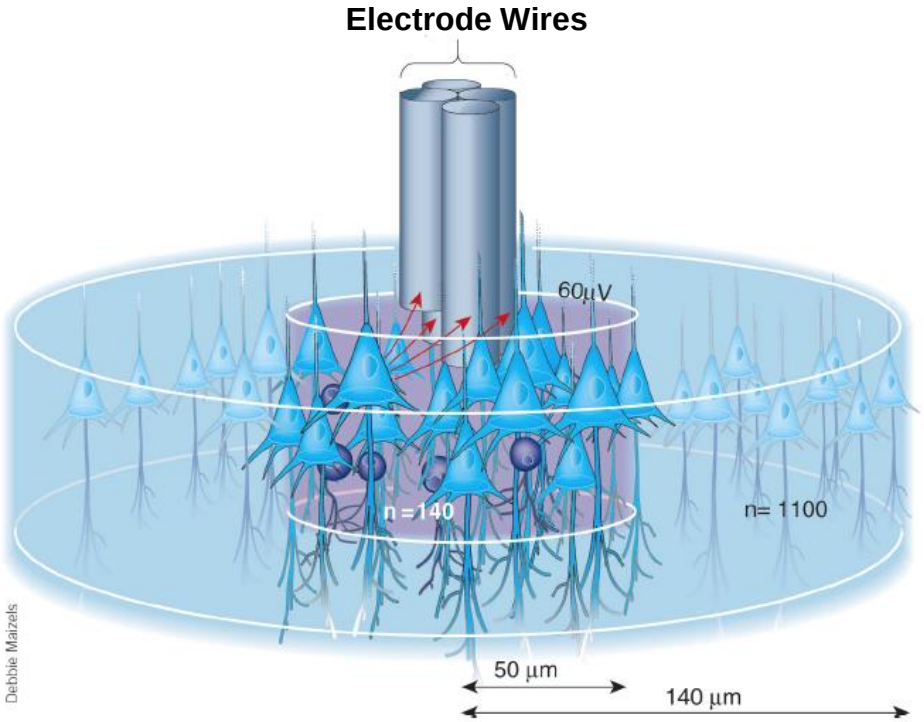




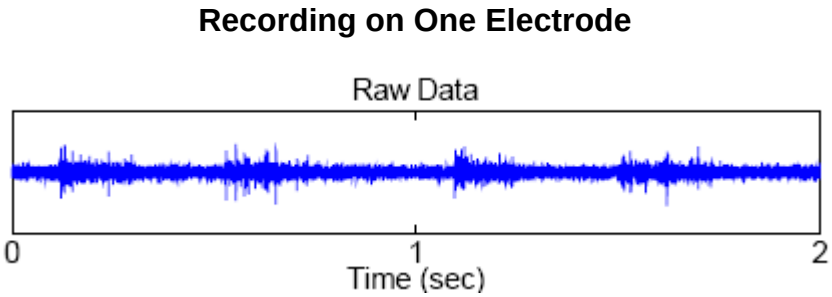
Brain-Machine Interfaces (BMIs)

- Invasive neural interfaces are often termed as Brain-Machine Interfaces (BMIs)

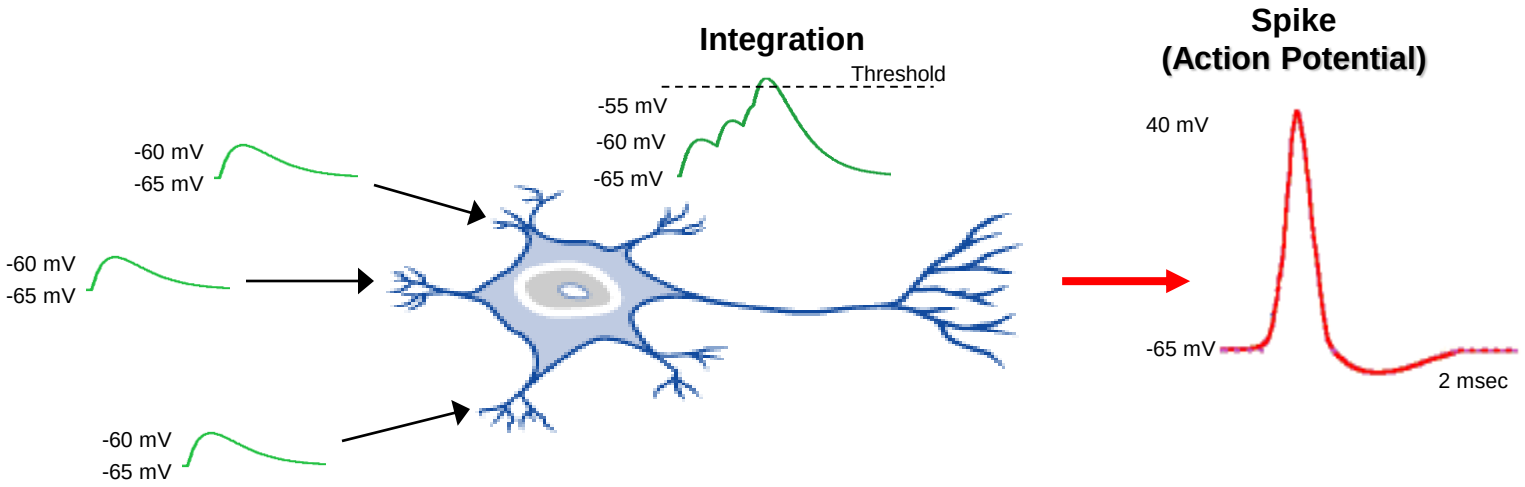
- BMI approaches are based on recordings from groups of single neurons (also known as single units) or on the activity of multiple neurons (also known as multi-units)



(Buzsaki, 2004)



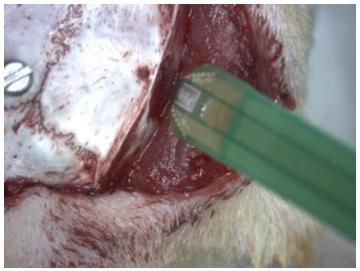
Neural Activity



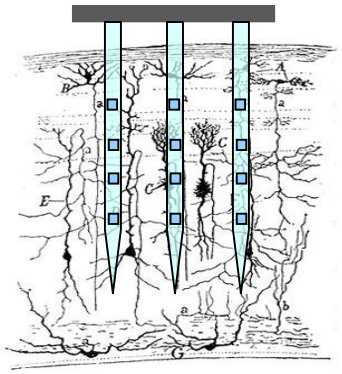
Features

1. Spike shape is stereotypical (all-or-none firing)
2. Communication between neurons is either excitatory or inhibitory
3. There is a synaptic delay between connected neurons

Signals Processing

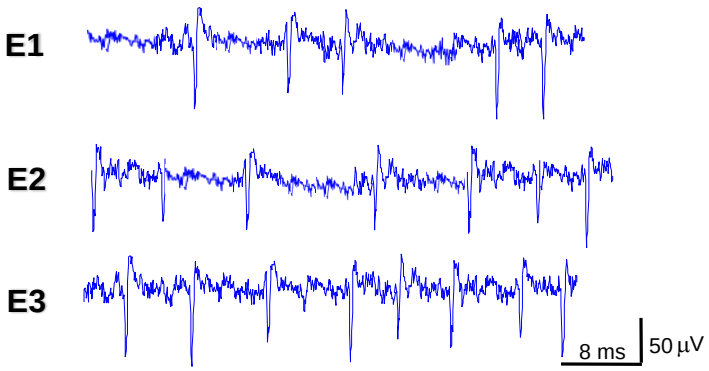


Implant

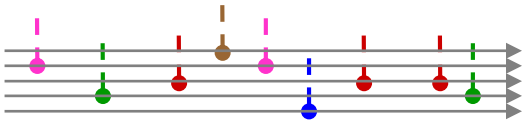


Record

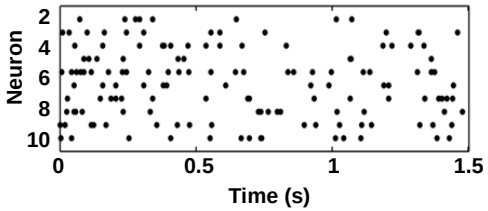
Multi-electrode Recordings



Spike Detection & Sorting



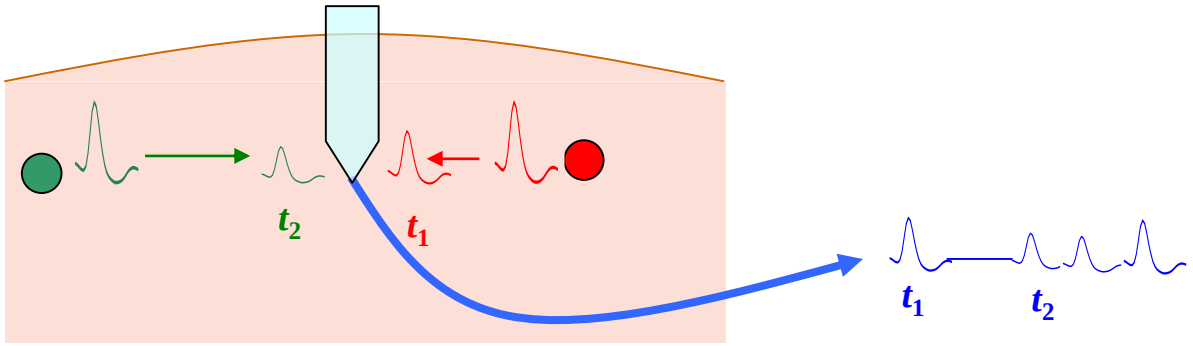
Spike Trains



K. Y. Kwon, S. Eldawlatly and K. G. Oweiss, "NeuroQuest: A Comprehensive Analysis Tool for Extracellular Neural Ensemble Recordings," *Journal of Neuroscience Methods* 204(1), pp. 189-201, 2012

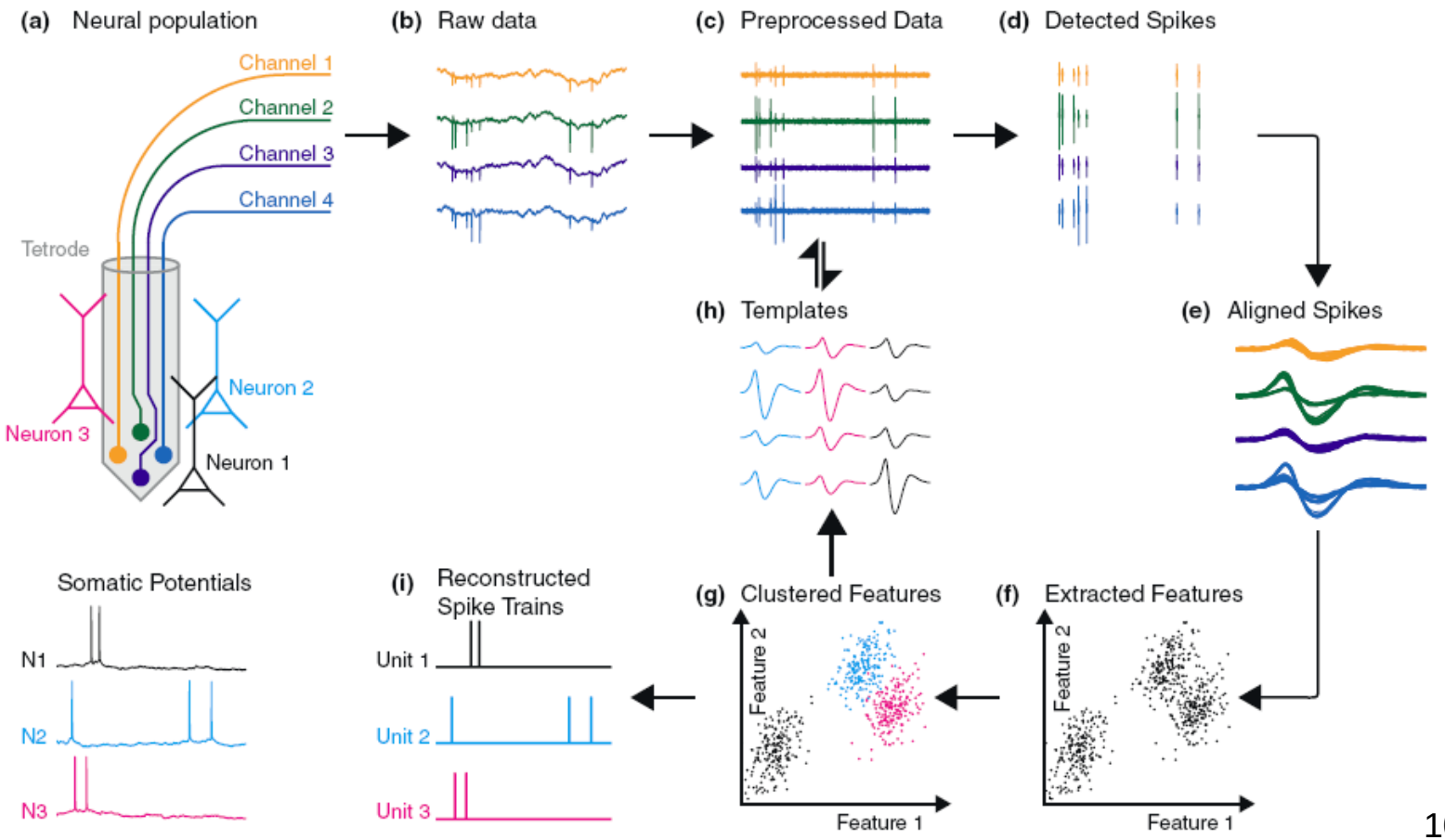
Signals Processing

- Extracellular Recording of Neural Activity



Spike Sorting

- It is usually necessary to identify the activity of different neurons recorded on the same electrode (The process of Spike Sorting)



(Einevoll, 2012)

Spike Sorting

- Although spikes of all neurons are stereotypical with the same shape when measured intracellularly, they would have different shapes when recorded extracellularly

- K-means clustering can be used here to identify the spikes belonging to different neurons

- One problem is how to know the number of units recorded (the value of K)

- This can be determined visually only if all spikes are represented in a 2D space

- In the project, extract two features from each spike as follows:
  - The standard deviation of the samples of the spikes
  - The maximum difference between two successive samples of the spike

Spike Sorting