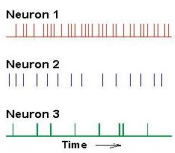
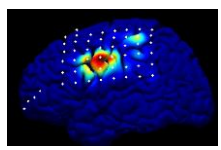
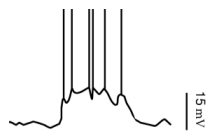
CSE 599E

Lecture 3:

Recording/Stimulation Techniques



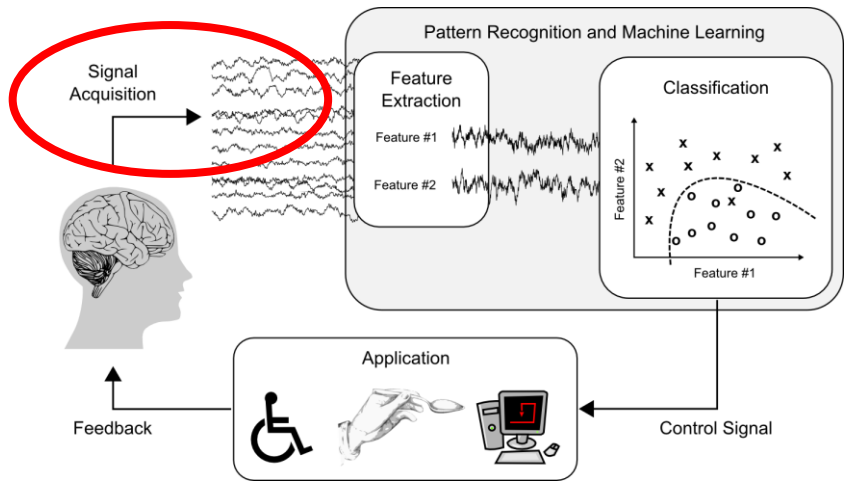




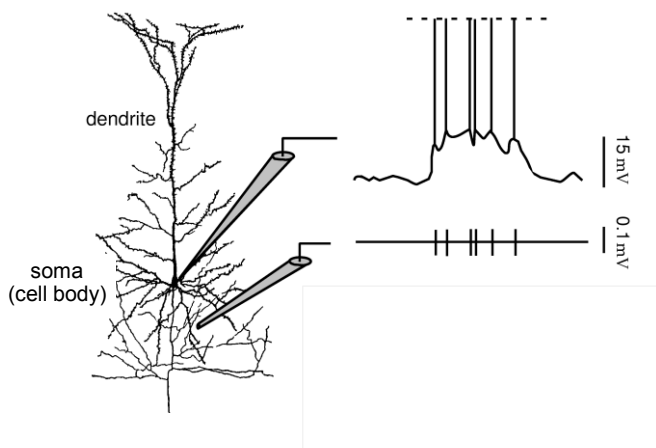
What's on the menu?

- Recording and Stimulation Techniques
  - Invasive
  - Semi-Invasive
  - Non-Invasive

Components of Brain-Computer Interfacing



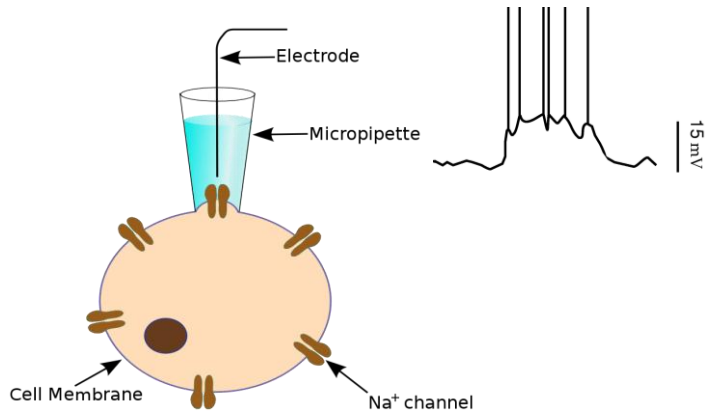
Invasive Recording



Intracellular Recording at the Soma

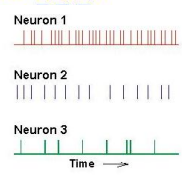
Extracellular Recording near the Soma

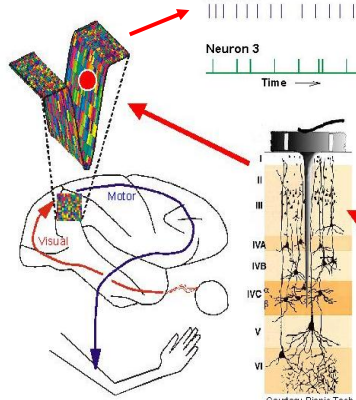
Intracellular Recording using Patch Clamp

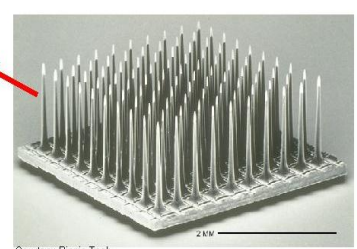


Extracellular Recording using Multielectrode Arrays

Extracellular recording of neural spikes





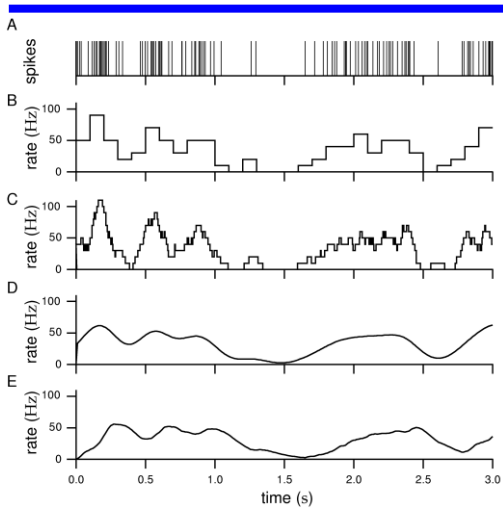


Array is implanted in an area of the cerebral cortex

Array of silicon electrodes with platinum-plated tips

(Work of Andersen & colleagues, Caltech)

From Spikes to Firing Rate



Extracellular spike train

Rectangular Window (100 ms)

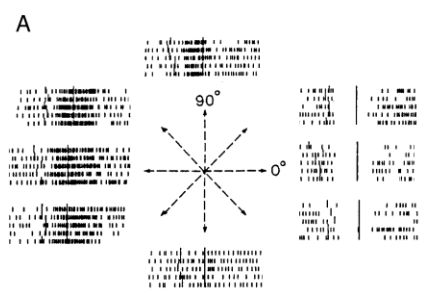
Sliding Window (100 ms)

Gaussian Window (σ = 100 ms)

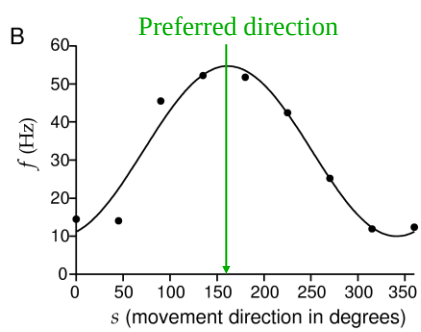
Causal Window ($1/\alpha$ = 100 ms)

From Firing Rates to Tuning Curves:

Tuning Curve of a Neuron in Primary Motor Cortex (M1)

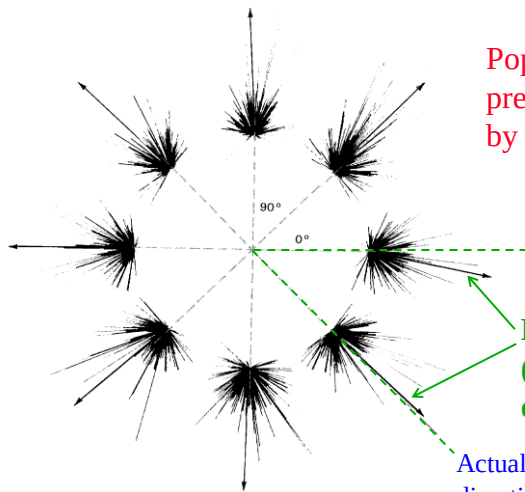


Spike trains as a function of hand reaching direction



Cosine Tuning Curve

Movement Direction can be Predicted from a Population of M1 Neurons' Firing Rates



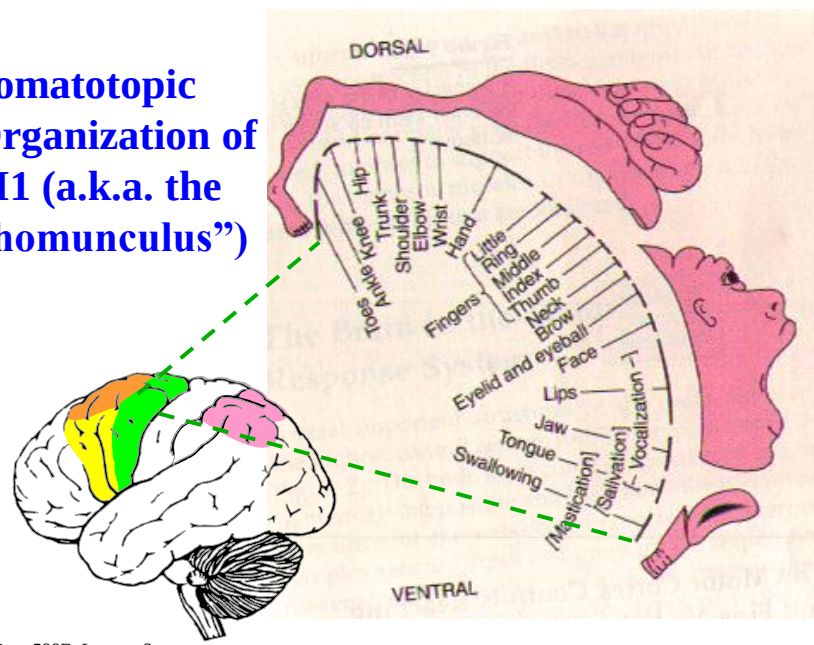
Population vector = sum of preferred directions weighted by their firing rates

Actual arm movement direction

Population vectors (decoded movement direction)

Actual arm movement direction

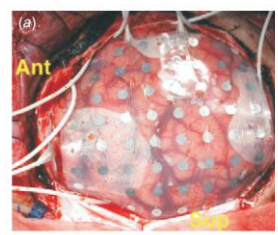
Somatotopic Organization of M1 (a.k.a. the "homunculus")

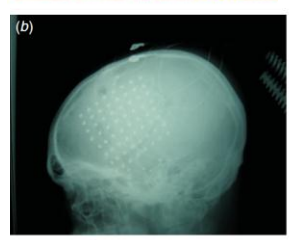


Semi-Invasive Recording

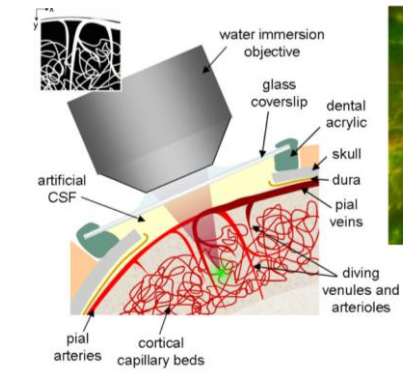
Electrocorticography

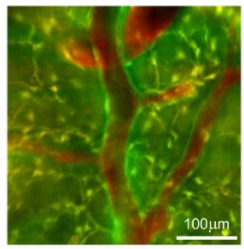
(photo courtesy Seattle Times)



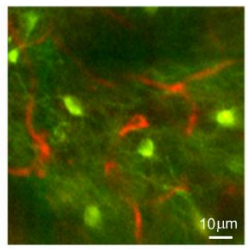


Optical Imaging





Oregon Green calcium sensitive dye stained neurons



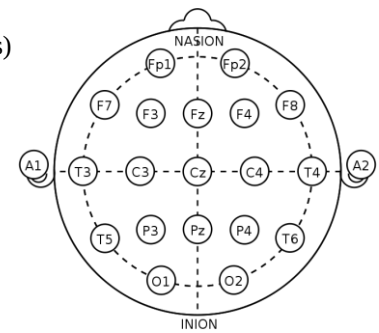
Transgenic mouse expressing green fluorescent protein (GFP) in a subpopulation of neurons

Non-Invasive Recording

Electroencephalography (EEG)

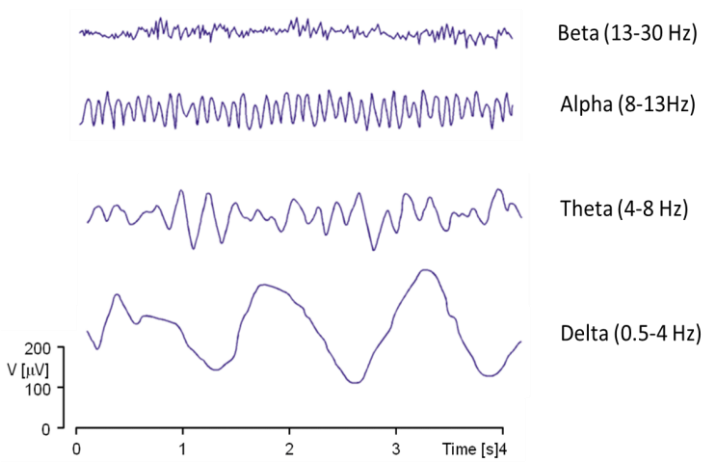
Measures electrical fluctuations caused by post-synaptic potentials from thousands of neurons oriented radially to scalp

- Tens of microvolts range
- Poor spatial resolution (cm^2)
- Good temporal resolution (ms)



10-20 System for Electrode Locations

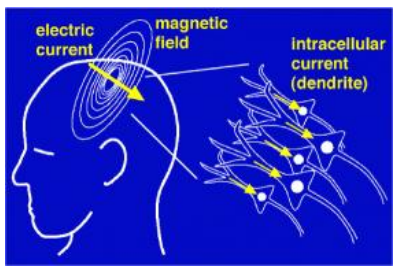
Example of EEG Oscillatory Potentials



Magnetoencephalography (MEG)

Measures magnetic fields produced by activity of thousands of cortical neurons oriented perpendicular to the cortical surface

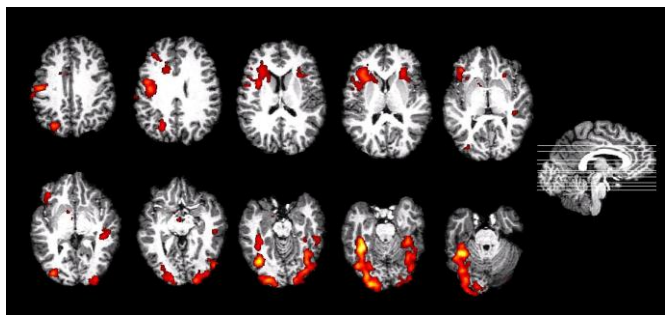
- Magnetic fields not distorted by skull and scalp
- Better spatial resolution than EEG
- Expensive and bulky



Functional Magnetic Resonance Imaging (fMRI)

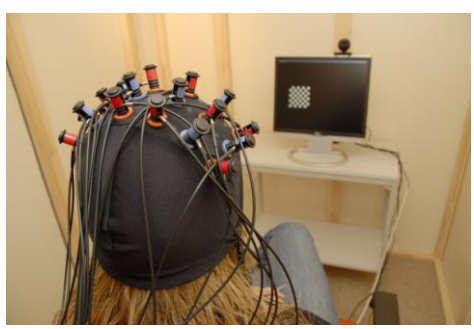
- Measures changes in blood flow due to increased activation of neurons in an area
- Relies on paramagnetic properties of oxygenated and deoxygenated hemoglobin in the blood
- Produces images showing blood-oxygenation-level-dependent signal changes (BOLD)

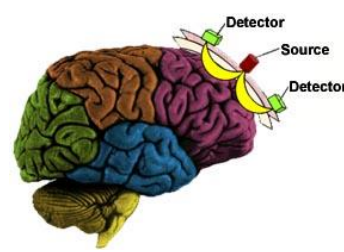
Example fMRI Images (word reading task)



http://www.med.nyu.edu/thesenlab/group/fmri.html

Functional Near-Infrared Spectroscopy (fNIR)

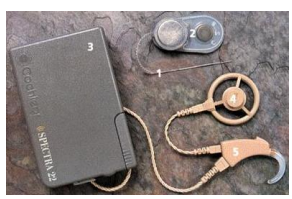


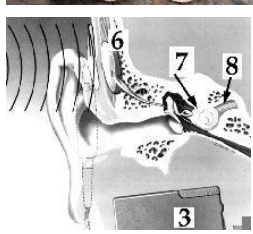


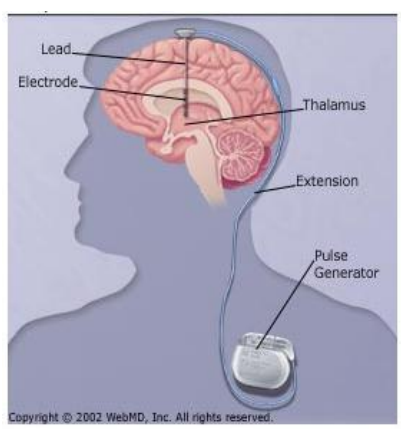
Stimulation

Extracellular Microelectrodes

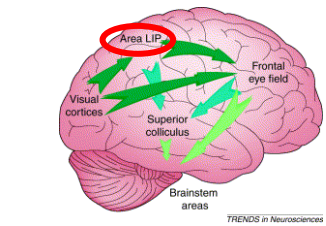
- Examples: Cochear implant, DBS

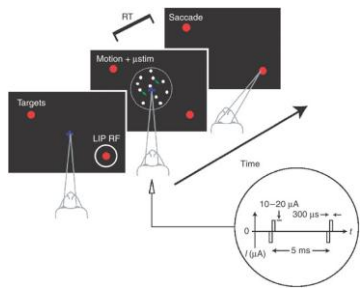


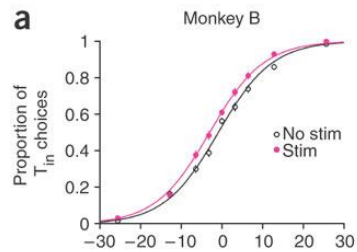


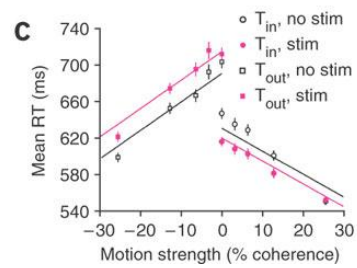


Microstimulation can alter decision making



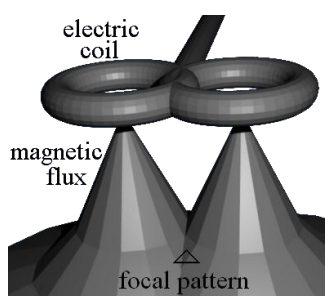






(Hanks et al., 2006)

Transcranial Magnetic Stimulation (TMS)



Next Class:
Signal Processing and
Machine Learning for BCI