Computational Neuroscience - Lecture 1

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8 May 2018
Outline

1. Brief introduction to computational neuroscience
2. Brain signal measuring
3. Acquisition of EEG
4. Referencing EEG methods
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3. Acquisition of EEG
4. Referencing EEG methods
Main aspects:

1. Computer processing and analysis of medical images of the brain (single-photon emission computed tomography (SPECT), positron emission tomography (PET), Magnetic resonance imaging (MRI) and functional MRI (fMRI)).

2. Experimental data analysis of brain signals

3. Models for micro-/macro- structures and dynamics (from neuro to brain level)
Brain signals:

- **scalp electroencephalograms (EEG):**
  - Electric field generated by neural activity through electrodes attached to the scalp.
  - The electrode at each position records the difference in potential between this electrode and a reference one.
  - Enables the localization of all possible orientations of neural sources.
  - The recorded electrical activity is affected by conductivity from brain to scalp.

- **magnetoencephalograms (MEG):**
  - Recording based on ultrasensitive superconducting sensors (SQUIDS), which are placed on a helmet-shaped device.
  - The magnetic fields are generated by the neural activity (coherent activity of dendrites of pyramidal cells).
  - No conductivity boundaries.
  - Only vertical to scalp orientations of neural sources can be recorded.

- **Electrocorticograms (ECoG), interictal EEG (iEEG)**
**Electrodes:**

low-impedance electrical contact with the scalp, placement (10-20 system, other variations for high-density EEG), numbering / notation, recording reference.

source: https://www.bci2000.org/mediawiki/
**Amplifiers:**
magnify the size of the signal (from microvolts up to several volts),
gain: ratio of output to input signal (e.g. 100000),
Differential amplifiers:
most sources of electrical noise are of similar amplitude in nearby regions of the body,

common-mode signals: potentials similar at different electrode sites,

recording reference: a reference signal to subtract

differential-mode signal: obtained from subtracting “active” from “reference”
Filters (prior to digitation)

High-pass filter

Low-pass filter

Notch filter: eliminates the frequencies matching that of the power line, e.g., 50 Hz in Europe.

Broad bandpass filter: combination of high- and low-pass filter, e.g., 0.1 to 70 Hz.
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Aliasing

Nyquist theorem limits the sources at higher frequencies that can be captured.

Higher frequencies can give artifacts in the digitized output.
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anti-aliasing filter: low-pass filter with cut-off at the Nyquist frequency
Electroencephalogram: Acquisition process - 6

Analog-to-Digital Conversion

sampling frequency, e.g. 200 Hz, (Nyquist theorem)
amplitude, e.g. 24 bits preictal activity
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ictal activity
Digital EEG acquired at **referential montage** (recording reference), e.g. ear, normal-like activity

+ ideal for generalized abnormalities
- contaminated by local abnormal activity, e.g. temporal lobe for ear REF.
Montage reformatting: common average

Excluding first corrupted channels?

+ ideal for focal activity - contaminated with generalized abnormal activity
**Montage reformatting:** *common average*

Excluding first corrupted channels?

+ ideal for focal activity
- contaminated with generalized abnormal activity
Montage reformatting: Bipolar montage

+ Sharp distinction
- Distortion of wave, widespread potentials may be canceled, end of chain problem
Example:

source: http://www.mc.vanderbilt.edu
No 2 Hz activity

2 Hz activity

2 Hz activity

No 2 Hz activity

No 2 Hz activity