Filters

Mariella Paul
paulm@cbs.mpg.de

MPI for Human Cognitive and Brain Sciences
Berlin School of Mind and Brain

Deconstructing the EEG signal

- signals can be deconstructed into sine waves of different frequencies
- this can be achieved with **Fourier analysis**, a mathematical process that allows you to compute the sine waves whose sum is equal to your signal

Fourier analysis

- any waveform, independent of complexity, can be reconstructed by summing up a set of sine waves
- Fourier analysis takes a signal and returns the set of sine waves that can be summed up to reconstruct that signal
- importantly, sine waves returned this way **can be, but are not necessarily a real part of a signal**
- for example, if a Fourier analysis returns a sine wave with a frequency of 10 Hz, your EEG signal may, but does not have to, contain an oscillation at 10 Hz

Fourier transformation

- filters use Fourier transformation
- Fourier transformation transforms information from the time domain (such as ERP waves) to the frequency domain
- outputs the amplitudes of each frequency present in the signal
- inverse Fourier transformation transforms the frequency domain back to the time domain

Luck (2011) *MIT Press*

Filters

- filters are used to suppress noise in the EEG signal
- filters can be named according to
  - what they suppress (dirt filter)
  - what they let pass (coffee filters, air filters)

By Elke Wetzig (Elya) (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC-BY-SA-3.0], via Wikimedia Commons

Filters

- common EEG terminology:
  - low-pass: filters that let frequencies *below* a certain cutoff *pass*
  - high-pass: filters that let frequencies *above* a certain cutoff *pass*
  - band-pass: filters that let frequencies *between* two cutoffs *pass*
  - band-stop or notch filter: filters that *suppress* frequencies *between* two cutoffs
- using a band-pass filter with cutoffs X and Y is the same as using a low-pass filter with cutoff Y and a high-pass filter with cutoff X

Exercise

Assume you have an EEG signal with frequencies between 0.001 and 100 Hz. Which frequencies are left after applying the following filters?

- a low-pass filter at 1 Hz
- a high-pass filter at 1 Hz
- a low-pass filter at 70 Hz
- a band-pass filter at 0.1 and 30 Hz

Exercise

- using ft_preprocessing, play around with filters
- for example, try
  - try high-pass filters with half-amplitude cutoffs of 0.3, 1, and 10
  - try low-pass filters with half-amplitude cutoffs of 10, 20, 30, and 100
- use the code on the next slide
- plot your EEG signal after applying each filter
- which filters do you think are useful?

Filter cutoffs

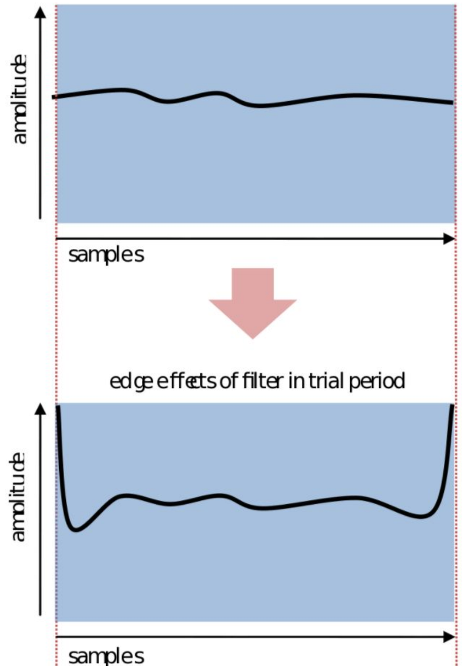
- in ideal world, we would like to completely suppress the frequencies that contain noise and let the frequencies that contain real signal pass completely
- however, this isn’t possible; instead, each filter has a range of frequencies
  - it lets pass almost completely
  - it suppresses almost completely
  - it suppresses partially

Filter terminology

- **half-amplitude cutoff**: the frequency for which a filter lets 50% pass and suppresses 50%
- **pass-band**: the frequencies that the filter lets pass completely
- **stop-band**: the frequencies that the filter suppresses completely
- **transition width**: the frequencies that are suppressed partially
- **steepness**: the slope of the filter

When to filter?

- filtering can introduce **edge artifacts**, i.e. artifacts at the beginning and the end of the signal
- to prevent this, it is best to filter continuous instead of segmented data



http://www.fieldtriptoolbox.org/tutorial/automatic_artifact_rejection

Filter recommendations

- filters distort signals, so they should be chosen very carefully
- filters should be chosen based on what you're interested in
- for ERPs these filters are usually acceptable (based on Luck, 2011):
    - high-pass filter with 0.1 Hz cutoff, to suppress slow voltage changes like sweating
    - low-pass filter with 30 Hz cutoff to suppress muscle artifacts and line noise
    - if you're interested in very slow components, you may need a lower cutoff for the high-pass filter

Filtering in FieldTrip

- filter your data with these final options:
    - high-pass filter cutoff: 0.3 Hz
    - low-pass filter cutoff: 30 Hz