



# The electroencephalogram (4)

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# A plan for today

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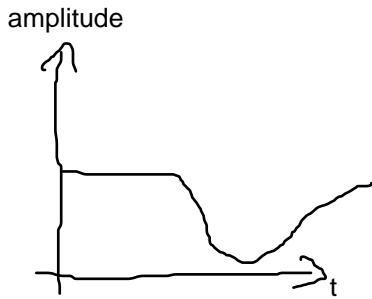
- Finish skimming EEG analyses
- Introduce a set of tools and equipment that you may want to deal with
- ~~Start the course section on Electromyography~~
- Start a hands-on minicourse on signal processing
  - Frequency analysis
  - Filtering

# Time-frequency analysis

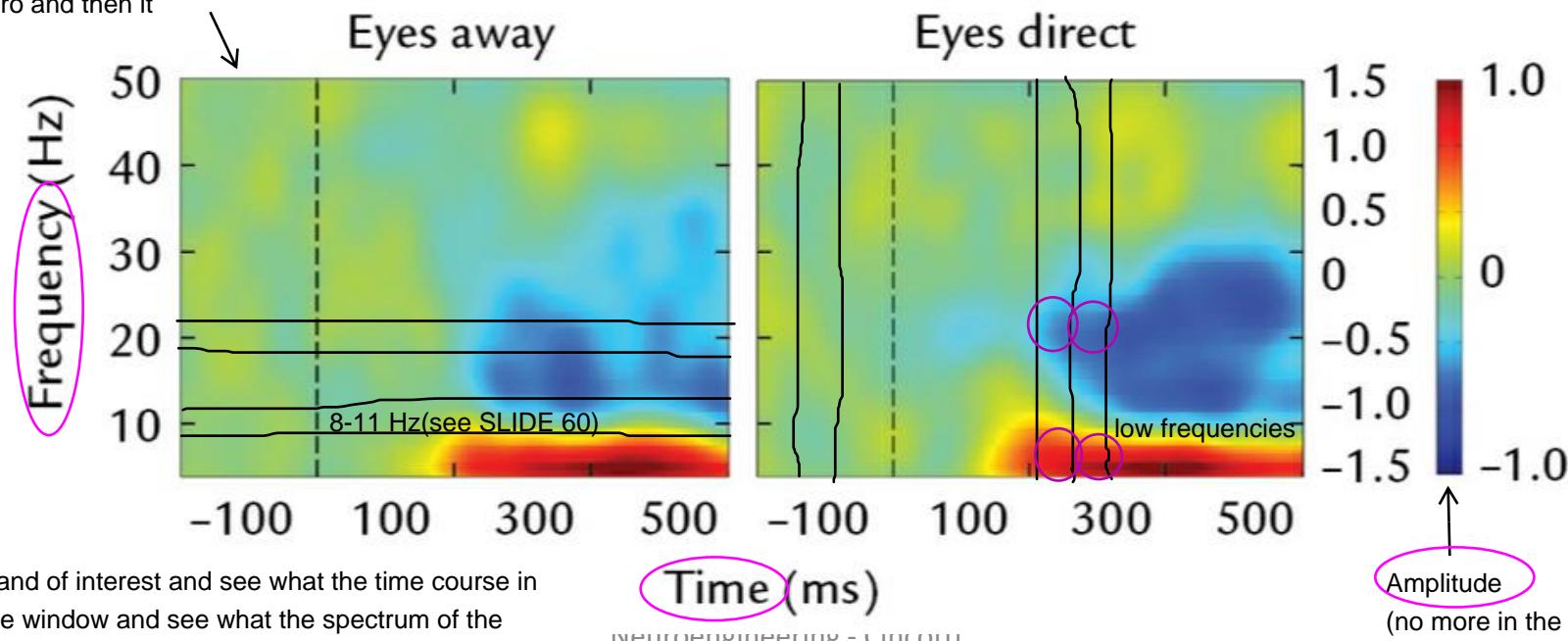
It's able to make the analysis of the spectrum of the signal in a time varying meter

- Time-frequency analyses go one step further by computing and visualizing the spectral or amplitude content of the signal as a function of time simultaneously for all frequencies of interest.
- Fourier transforms, Hilbert transforms, and wavelet-based approaches can be used to calculate MEG/EEG signal power (amplitude)
- Using this procedure, features in MEG/EEG data can be visualized in both time and frequency.

In the range 8-11 Hz the frequency was first zero and then it increases(yellow), at 20Hz first was zero and then it decreases(blue)



the x axes(that previously was the amplitude), now is used for another domain(frequency)

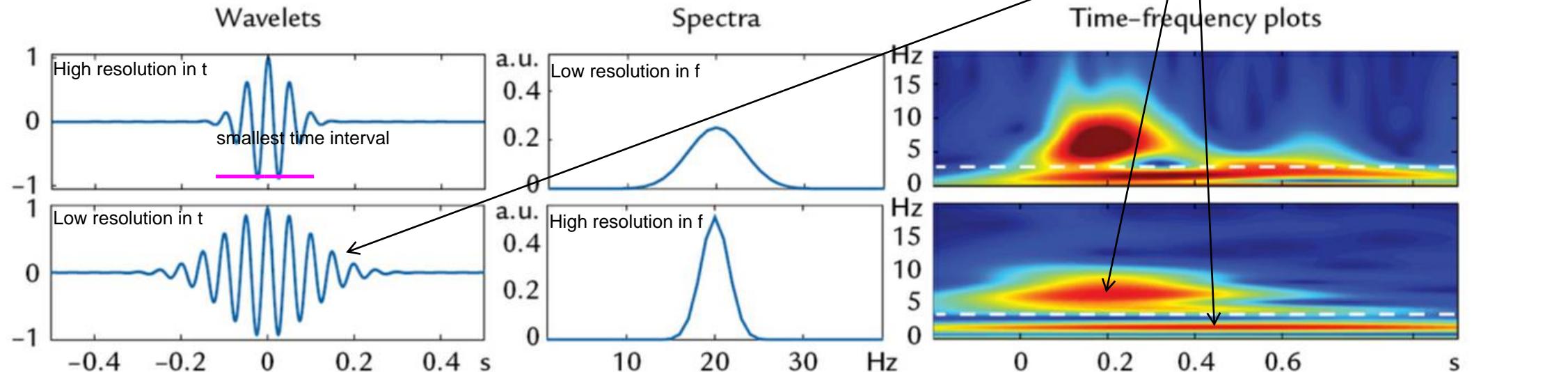


For analize that you can take some band of interest and see what the time course in this band of interest or take a small time window and see what the spectrum of the signal is in this window

# Time-frequency analysis – «indetermination principle»

- Improving time resolution worsens spectral resolution (and vice versa)

This two panels analyze the same signal



You can't have high time resolution and high frequency resolution at the same time (you can achieve tools but you will have a marginal improvement)  
In the upper panel you will have a better resolution in the horizontal axis, in the lower panel you will have a better resolution in the vertical axis

# Further reading

# Project related readings

Not necessary to read

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- Ch 12. auditory responses, including steady-state
- Ch 13. visual responses, including steady-state
- Ch 14. somatosensory responses
- Ch 16. motor function
- Ch 17. change detection (CNV, MMN, P300, ErrN, ...)

# Software tools

The screenshot shows the homepage of the BCI2000 website, which is part of the NCAN (National Center for Adaptive Neurotechnologies) platform. The page features a dark header with the NCAN logo and the text "National Center for Adaptive Neurotechnologies". Below the header, there is a navigation bar with links for "Main page", "Discussion", "Read", "View source", "View history", and a search bar. A large graphic on the left side contains the BCI2000 logo and links to "Main page", "Recent changes", "Random page", and "Help". The main content area is divided into several sections: "Getting Started with BCI2000" (with a list of introductory steps), "User Tutorials" (circled in pink), "User Reference Manual" (circled in pink), "Technical Reference", "Programming Reference", and "System Features". A black arrow points from the "User Reference Manual" section towards the bottom-left of the page.

Main page Discussion Read View source View history Search

Main page Recent changes Random page Help

Tools What links here Related changes Special pages Printable version Permanent link Page information

Getting Started with BCI2000

- Create or modify a User Account,
- Download BCI2000 Binaries,
- Take the introductory BCI2000 Tour to learn about using BCI2000,
- Get access to the BCI2000 Source Code.

User Tutorials

Tutorial guides to your first successful experiments:

- Mu Rhythm BCI Tutorial,
- P300 BCI Tutorial.

Introductions to data analysis and interpretation:

- Data Analysis Tutorials.

User Reference Manual

The User Reference Manual describes all details of system configuration and usage:

- Online System Reference,
- Filters and Parameters,
- BCI2000 Tools Reference.

Technical Reference

The Technical Reference Manual contains information on

- BCI2000 Online System Design,
- Transmission Protocol Definition,
- External Interfaces.

Programming Reference

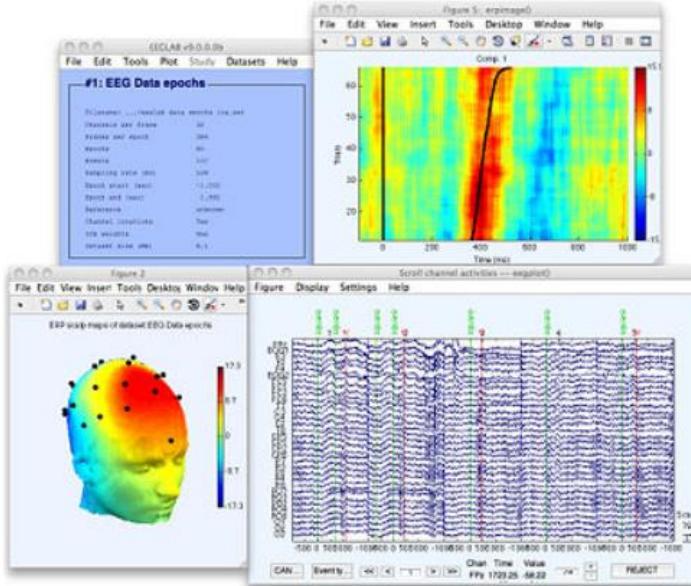
System Features

For more advanced tools that are not in the "User Tutorials"

<https://www.bci2000.org>

# EEGLab

Is a toolbox for MatLab



The screenshot displays the EEGLab software interface. The top window, titled '#1: EEG Data epochs', shows a spectrogram with time on the x-axis (0 to 1000 ms) and frequency on the y-axis (20 to 60 Hz). A vertical black line marks a specific component labeled 'Comp. 1'. The bottom window, titled 'EEG scalp maps of dataset EEG specific', displays a 3D head model with electrode positions and corresponding scalp maps. Below the head model is a grid of raw EEG waveforms for multiple channels over time.

## What is EEGLAB?

EEGLAB is an interactive Matlab toolbox for processing continuous and event-related EEG, MEG and other electrophysiological data incorporating independent component analysis (ICA), time/frequency analysis, artifact rejection, event-related statistics, and several useful modes of visualization of the averaged and single-trial data. EEGLAB runs under Linux, Unix, Windows, and Mac OS X.

<https://sccn.ucsd.edu/eeglab/index.php>

# Matlab

We will use it to learn very basic signal process

The screenshot shows the MathWorks MATLAB Online landing page. At the top, there's a navigation bar with links for Products, Solutions, Academia, Support, Community, Events, and a 'Get MATLAB' button. Below the navigation is a search bar labeled 'Search MathWorks.com'. The main content area features a large image of a person's hands typing on a laptop keyboard, with the MATLAB interface visible on the screen. The text 'MATLAB Online' and 'Use MATLAB through your web browser' is displayed, along with a blue 'Start using MATLAB Online' button. A note at the bottom states: 'MATLAB Online is available with select licenses. [Check your eligibility.](#)'

<https://www.mathworks.com/products/matlab-online.html>

The screenshot shows the Sapienza Università di Roma Software download page. At the top, there are logos for Sapienza Università di Roma and InfoSapienza CAMPUS Software. A grey sidebar on the right displays a welcome message: 'Campus Uniroma1 RESTRICTED area', 'Welcome febo cincotti, logged as: Personale', 'your mail is: Febo.Cincotti@uniroma1.it', 'your ip address is: 151.100.47.183', and a 'logout' link. The main content area has a heading 'Software available for download' and a note: '(Note: use Firefox if the ftp page is not visible or the ftp link is broken)'. Below this is a table with four rows, each listing a software title, its installation information, and a download link.

Software	Installation info	Download link
<b>IBM SPSS</b>	<a href="#">info</a>	<a href="#">SPSS</a>
<b>Sas</b>	<a href="#">Download SetINIT file</a>	<a href="#">SAS</a>
<b>The MathWorks</b>	<a href="#">Download license.dat and activation key</a>	<a href="#">Matlab</a>
<b>WOLFRAM RESEARCH</b>	<a href="#">Info on license server</a>	<a href="#">Mathematica</a>

<http://bit.ly/install-matlab-sapienza>

It is developed in Python

Magnetoencephalography  
(you do not measure potential  
but magnetic fields)

This is more strong for  
MEG and not so much  
for EEG

The screenshot shows the MNE (Magnetoencephalography) website homepage. At the top, there is a navigation bar with links for Install, Overview, Tutorials, Examples, Glossary, API, Contribute, and a version dropdown set to v0.19.2. A search bar is also present. The main title "MNE" is displayed in large, stylized letters with a color gradient from blue to red. Below it, the subtitle "MEG + EEG ANALYSIS & VISUALIZATION" is shown, with "MEG" highlighted by a pink circle. To the left of the main title, there is explanatory text about Magnetoencephalography. On the right side, there are three sections: "Multi-core CPU & GPU.", "Usability" (with an eye icon), and "Flexibility" (with a grid icon). Below these sections is a large image showing two brain topographies and a spectrogram with a color scale from 0 to 125. The text "Data visualization." is overlaid on this image, along with the subtext "Explore your data from multiple perspectives." and a "Check it out" button. At the bottom, there are three buttons: "Data I/O", "Preprocessing", and "Visualization".

<https://mne.tools/>

# Freely available datasets

The database of EEG is not so large

PhysioNet is a database for physiological signals including electro physiological signals



## Databases

Clinical

Waveform

Multiparameter

ECG

RR Interval

Other Cardio

Gait and Balance

Neuroelectric

Synthetic

Image

Miscellaneous

## Suggested Citation

If you use resources from PhysioNet in a publication, please credit the author(s) using the citation displayed at the top of the published content. Please also include the standard citation for PhysioNet:

Goldberger AL, Amaral LAN, Glass L, Hausdorff JM, Ivanov PCh, Mark RG, Mietus JE, Moody GB, Peng C-K, Stanley HE. PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals. *Circulation* **101**(23):e215-e220 [Circulation Electronic Pages; <http://circ.ahajournals.org>].

## Overview

This page displays a curated list of our databases. You can search our resources.

- [Clinical Databases](#): Includes databases of clinical measurements, physiological signals, and imaging reports.
- [Waveform Databases](#): Includes databases of waveform measurements organized according to their source.
- [Multi-Parameter Databases](#): Includes databases of multi-parameter measurements, such as blood pressure, respiration, and heart rate.

## Neuroelectric and Myoelectric Databases

- [Class 2] [CHB-MIT Scalp EEG Database](#): EEG recordings of 22 pediatric subjects with intractable seizures, monitored for up to several days following withdrawal of anti-seizure medication to characterize their seizures and assess their candidacy for surgical intervention. In all, the onsets and ends of 182 seizures are annotated.
- [Class 2] [EEG During Mental Arithmetic Tasks](#): The database contains EEG recordings of subjects before and during the performance of mental arithmetic tasks.
- [Class 2] [EEG Motor Movement/Imagery Dataset](#): One- and two-minute recordings of 109 volunteers performing a series of motor/imagery tasks. Each record contains 64 channels of EEG recorded using the BCI2000 system, and a set of task annotations.
- [Class 2] [EEG Signals from an RSVP Task](#): This project contains EEG data from 11 healthy participants upon rapid presentation of images through the Rapid Serial Visual Presentation (RSVP) protocol at speeds of 5, 6, and 10 Hz.
- [Class 2] [Effect of Deep Brain Stimulation on Parkinsonian Tremor](#): Rest tremor velocity in the index finger of 16 subjects with Parkinson's disease, who receive chronic high frequency electrical deep brain stimulation.
- [Class 2] [ERP-based Brain-Computer Interface recordings](#): Annotated 64-channel EEGs with 4-channel EOGs sampled at 2048 Hz from 10 subjects; 20 short records for each subject, generated while focusing on

<https://physionet.org/about/database/#neuro>

## BCI Competitions



Here there are varius type of stimulation or spontaneus activity

- [BCI Competition I](#)
- [BCI Competition II](#) (also called BCI Competition 2003)
- [BCI Competition III](#) → Have been used by various paper to test a signal processing
- [BCI Competition IV](#) → tool change so a classification tool change

## References

Please help us to make the list of references complete and keep it up to date by reporting unlisted papers to [benjamin.blankertz@tu-berlin.de](mailto:benjamin.blankertz@tu-berlin.de), preferably PubMed ID (PMID) or in BibTex format.

- B. Blankertz, K.R. Møller, D.J. Krusienski, G. Schalk, J.R. Wolpaw, A. Schlögl, G. Pfurtscheller, J.d.e.I. R. Millen, M. Schröder, and N. Birbaumer. The BCI competition. III: Validating alternative approaches to actual BCI problems. *IEEE Trans Neural Syst Rehabil Eng*, 14:153-159, Jun 2006. [[pdf](#)]
- B. Blankertz, K.R. Møller, G. Curio, T.M. Vaughan, G. Schalk, J.R. Wolpaw, A. Schlögl, C. Neuper, G. Pfurtscheller, T. Hinterberger, M. Schröder, and N. Birbaumer. The BCI Competition 2003: progress and perspectives in detection and discrimination of EEG single trials. *IEEE Trans Biomed Eng*, 51:1044-1051, Jun 2004. [[pdf](#)]
- P. Sajda, A. Gerson, K.R. Møller, B. Blankertz, and L. Parra. A data analysis competition to evaluate machine learning algorithms for use in brain-computer interfaces. *IEEE Trans Neural Syst Rehabil Eng*, 11:184-185, Jun 2003. [[pdf](#)]

Questa è la slide più bella

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- Many more ...

# Devices

Low cost device for aquisition of electrophysiological signals

The screenshot shows the OpenBCI website homepage. At the top, there is a dark blue header bar with the "OPENBCI" logo on the left and navigation links for "SHOP", "DOCS", "COMMUNITY", "FORUM", "DOWNLOADS", "FAQ", and a search icon on the right. Below the header is a large banner image of a woman sitting on a red carpet, wearing a white EEG cap and working on a laptop. She is connected to various wires and sensors on the floor. Overlaid on the banner are several text boxes: "Open Source Tools for Neuroscience", "Widely-adopted and Trusted Equipment for Sensing the Brain & Body", and "EEG, EMG, ECG, and more!". Below the banner, the text "Open Source Brain-Computer Interfaces" is displayed. Further down, there is a section for "Freely Available Software (Free Raw Data)" with a link to "Github".

OpenBCI

SHOP DOCS COMMUNITY FORUM DOWNLOADS FAQ

Open Source Tools for Neuroscience

Widely-adopted and Trusted Equipment for Sensing the Brain & Body

EEG, EMG, ECG, and more!

● O O O

Open Source Brain-Computer Interfaces

Freely Available Software (Free Raw Data)

Find us on [Github](#)

<https://openbcicom/>

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**new**

<https://www.unicorn-bi.com/>

It is usefull for projects but is so expensive  
They have it at the hospital



Products / g.NAUTILUS RESEARCH

32 channel

# g.NAUTILUS RESEARCH

WEARABLE EEG HEADSET



\$\$\$\$

<https://www.gtec.at/product/gnautilus-research/>

It have 14 channels and works wetting the electrodes  
It is cheap but it is not so satisfying

EMOTIV

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