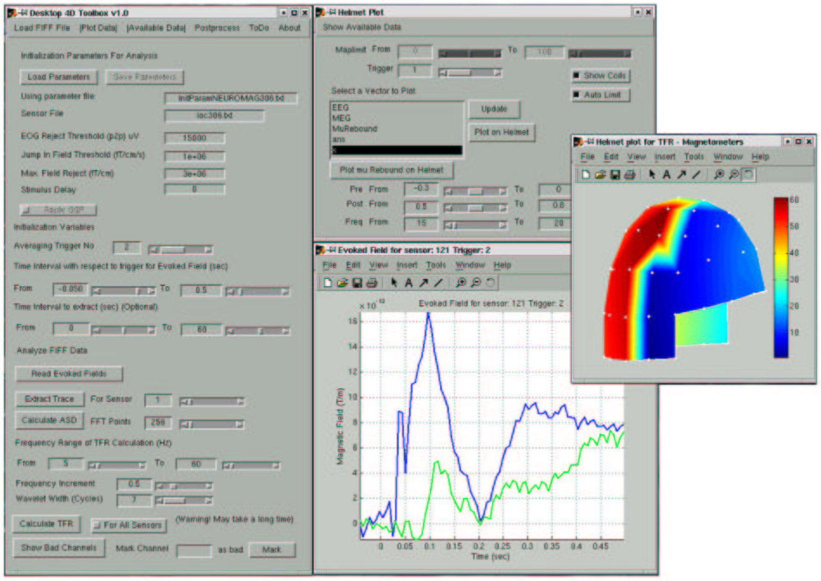


Using parameter file: InitParamNEUROMAG306.txt

Sensor File: loc306.txt

EOG Reject Threshold (p2p) uV: 15000

Jump In Field Threshold (fT/cm/s): 1e+06

Max. Field Reject (fT/cm): 3e+06

Stimulus Delay: 0

Averaging Trigger No: 2

Time Interval with respect to trigger for Evoked Field (sec)

From -0.050 To 0.5

Time Interval to extract (sec) (Optional)

From 0 To 60

For Sensor: 1

FFT Points: 256

Frequency Range of TFR Calculation (Hz)

From 5 To 60

Frequency Increment: 0.5

Wavelet Width (Cycles): 7

(Warning! May take a long time)

Mark Channel as bad

Maplimit From 0 To 100

Trigger: 1

EEG
MEG
MuRebound
ans
x

Pre From -0.3 To 0

Post From 0.5 To 0.8

Freq From 15 To 20

Evoked Field for sensor: 121 Trigger: 2

Desktop-4D-Toolbox (D4D) User Manual

Oguz Tanzer

October 8, 2002

http://syke.hut.fi/~tanzer/d4d

Contents

1 Introduction

Desktop-4D-Toolbox (D4D) is a window based data analysis platform for analyzing and visualizing magnetoencephalographic (MEG) data currently supporting Neuromag MEG Data. The analysis functions are based on scripts of 4D Toolbox by Ole Jensen and also employs the FIFF (Neuromag Data Format) to MAT conversion routines which are developed by Kimmo Uutela and the public distribution is supported by Neuromag Ltd.

The goal of this tool is to create an efficient and organized data analyzing environment for research on MEG data for neuroscientists.

It is designed with the idea that, the collected data can be analyzed relatively quickly by users with graphic handles such as edit boxes and data sliders.

The graphical user interface reduces the amount of repeated tasks by eliminating writing or changing of Matlab scripts to perform trivial operations to analyze the MEG data at hand.

An important design concept was to enable or disable the user when enough parameters are not present to analyze the given data. This includes the disabling of the fields regarding the analyzing function when enough parameters are not available.

Desktop-4D-Toolbox should also be well suited for unexperienced users, who want to learn about the effect of certain parameters on the MEG data quickly.

2 To whom this package is designed for?

The D4D is designed especially for people without computer programming or script programming background, but would like to analyze MEG data with the tools provided with the 4D Toolbox.

Users with computer programming background, or who find this package limiting can also refer to the scripts of 4D-Toolbox. Users can also refer to 4D-Toolbox manual for further information on availability of the tools.

The main features of the D4D include:

- Analyzing MEG data without writing scripts
- Better interaction with data using graphical adjustment of parameters and data hiding
- More organized data analysis

Machine Type	**Matlab version**	**operating system**
IBM-PC	Matlab 6.1	Linux
IBM-PC	Matlab 6.1	MS Windows 2000*
HP	Matlab 6.1	HP-UX

Table 1: Machines and operating systems on which D4D has been tested (as of September 2002)

- Colored views of files in current directory with *bookshelf* approach
- Some data post-processing
- Changing graph view parameters for nice printouts (Future version)
- Usability under various environments with Matlab

3 System Requirements

The software is designed and written under Matlab and works under Matlab 5.x and Matlab 6.x versions. It requires that the FIFF to Matlab routines and 4-D Toolbox scripts are in the same directory as the D4D components. The raw FIFF to Matlab conversion routines are pre-compiled binaries are tested to work in HP-UX and Linux systems.
Table 1 shows the platforms this package is tested. *Since D4D is implemented completely in Matlab, it is possible to use the package in any environment where Matlab is supported, but the FIFF to Matlab conversion routines currently work only under Linux and HP-UX. However, other data, saved in Matlab ".MAT" format could be analyzed. For example, extracted data could be sent to an MS Windows environment and other tasks could be performed.

4 Development and Licence

The D4D is designed and written by Oguz Tanzer at Laboratory of Biomedical Engineering, Helsinki University of Technology.
The package is continuously updated so please check frequently for new function updates. It is user's own responsibility to check the results of the package. This is a new distribution and bugs in the package are inevitable. Please report them to `tanzer@syke.hut.fi` also feedback is very valuable and encouraged.
D4D is a free software (but not the conversion routines converting FIFF to Matlab format) This allows you to re-distribute and modify the functions

under the terms of the GNU general public licence as published by the Free Software Foundation.

5 Getting the D4D

All the components of the software can be downloaded from the D4D webpage: `http://syke.hut.fi/~tanzer/d4d`

The D4D requires 4D-Toolbox
(`http://boojum.hut.fi/~ojensen/4Dtools`)
scripts and the FIFF to Matlab conversion routines
(`http://boojum.hut.fi/~kuutela/meg-pd/`).
Please refer to their individual web pages on specific information about these software.

5.1 Installation

Use the following command to unpack the .TAR file:

```
>tar -xf d4d.tar
```

and follow the appropriate instructions below. If you already have 4D-Toolbox installed skip step 1 etc.

Steps of a *from scratch* installation are as follows:

1. Install 4D-Toolbox `http://boojum.hut.fi/~ojensen/4Dtools`

2. Install FIFF access routines `http://boojum.hut.fi/~kuutela/meg-pd/`

3. Extract d4d.tar to the same directory where the 4D-Toolbox scripts reside.

6 Learning to Use D4D by Example

In this section the components of the D4D is explained and how to use is explained via an example tutorial. This tutorial is the D4D version of the same material found in 4D-Toolbox manual. The same data file is used. The idea is that the user can perform the same operations as in 4D-Toolbox using the user interface following the protocol of D4D.

6.1 Getting Help

A nice part of the D4D is that, user is provided with pop-up tips on what each graphical object does. Also, each button is labelled intuitively regarding the function it performs.

6.2 Sample Data

The file `mnStim150.fif` used in the tutorial can be downloaded from the D4D webpage: `http://syke.hut.fi/~tanzer/d4d` or from the 4D-Toolbox webpage: `http://boojum.hut.fi/~ojensen/4Dtools`
After downloading move the file to the working directory and unzip using the command:

```
>gunzip mnStim150.fif.gz
```

The FIFF file `mnStim150.fif` contains raw MEG data recorded by Neuromag Vectorview system (306 sensors) and the data are from an experiment in which a subject received alternating stimuli to the left and right median nerve at wrists. The times of left and right hand stimulation are respectively marked by trigger channel 1 and 2. There are about 200 stimuli per hand. The interstimulus interval was 3 second, each side. The data were digitized at 600Hz [1].

7 Using D4D

Open Matlab and goto the directory where D4D and 4D-Toolbox are installed. Enter command:

```
>d4d
```

The main window shown in Figure 1 will come up and the program is ready to start.

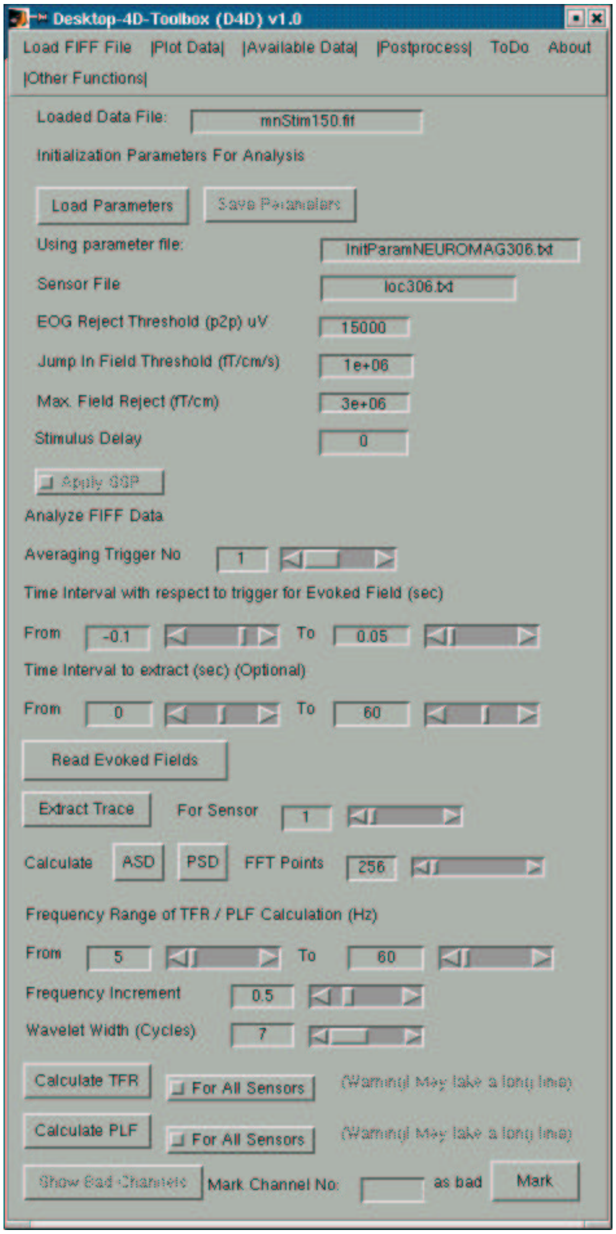
Make sure the data file is in the same directory as the programs files. In future versions possibly a separate data directory could be possible.

As explained above, the interface of D4D will be explained with an example. This is the same example found in 4D-Toolbox manual, so previous users could be familiar to this one.

7.1 File Name Convention

The D4D has a unique but simple file naming convention with an aim to organize the files after data analysis.

When an `inputfile` is loaded into the environment and an analysis is performed on the loaded data, the type of analysis is embedded into the output filename. A distinct view of the output data files in the current directory can be seen by pressing *Show Available Data* menu option on the main window. This results in the available data file window shown in Figure 2



Loaded Data File: mnStim150.fif

Initialization Parameters For Analysis

Using parameter file: InitParamNEUROMAG306.txt

Sensor File loc306.txt

EOG Reject Threshold (p2p) uV 15000

Jump In Field Threshold (fT/cm/s) 1e+06

Max. Field Reject (fT/cm) 3e+06

Stimulus Delay 0

□ Apply SSP

Analyze FIFF Data

Averaging Trigger No 1

Time Interval with respect to trigger for Evoked Field (sec)

From -0.1 To 0.05

Time Interval to extract (sec) (Optional)

From 0 To 60

For Sensor 1

Calculate ASD PSD FFT Points 256

Frequency Range of TFR / PLF Calculation (Hz)

From 5 To 60

Frequency Increment 0.5

Wavelet Width (Cycles) 7

□ For All Sensors (Warning! May take a long time)

□ For All Sensors (Warning! May take a long time)

Mark Channel No: as bad

Figure 1: The main window of D4D.

In this example case, the input filename is `mnStim150.fif`. Accordingly the output filename would be;

For Evoked Field of 1^{st} Trigger:
`out_ef_trig1_mnStim150.fif`
For Single Sensor Trace of 1^{st} Trigger for Sensor 1:
`out_trace_trig1_sensor1_mnStim150.fif`

These files can be seen from the *Available Data* menu option (Figure 1) once created.

In general the naming convention of the output files go as;

For Evoked Fields: `out_ef_trig<#>_<inputfile>`

For Single Sensor Traces: `out_trace_trig<#>_sensor<#>_<inputfile>`

For Amplitude Spectral Density: `out_asd_<inputfile>`

For Power Spectral Density: `out_psd_<inputfile>`

For Time Freq. Representation of 1 Sensor:

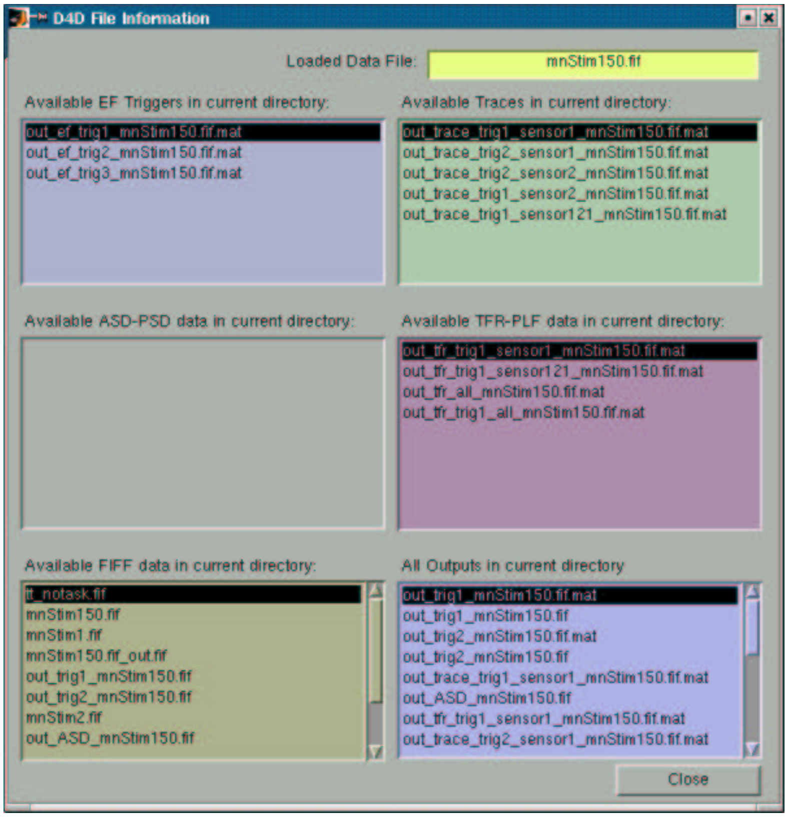
`out_tfr_trig<#>_sensor<#>_<inputfile>`

For Time Freq. Representation of All Sensors:

`out_tfr_trig<#>_all_<inputfile>`

7.2 Initialization of Sensor Thresholds

The parameters which define the threshold setting for the sensor rejection are displayed on the upper part of the main window as shown in Figure 3. The version 1.0 of the D4D does not allow changing of these parameters from the GUI.
If you want change some rejection parameters, simply open the parameter file shown in Figure 3 and edit the fields with a text editor. It is hoped that the future version will enable changing these from the user interface.



Loaded Data File: mnStim150.fif

Available EF Triggers in current directory:

out_ef_trig1_mnStim150.fif.mat
out_ef_trig2_mnStim150.fif.mat
out_ef_trig3_mnStim150.fif.mat

Available Traces in current directory:

out_trace_trig1_sensor1_mnStim150.fif.mat
out_trace_trig2_sensor1_mnStim150.fif.mat
out_trace_trig2_sensor2_mnStim150.fif.mat
out_trace_trig1_sensor2_mnStim150.fif.mat
out_trace_trig1_sensor121_mnStim150.fif.mat

Available ASD-PSD data in current directory:

Available TFR-PLF data in current directory:

out_tfr_trig1_sensor1_mnStim150.fif.mat
out_tfr_trig1_sensor121_mnStim150.fif.mat
out_tfr_all_mnStim150.fif.mat
out_tfr_trig1_all_mnStim150.fif.mat

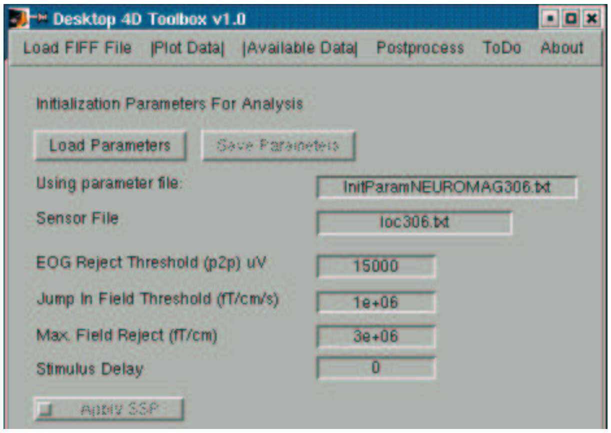
Available FIFF data in current directory:

tt_notask.fif
mnStim150.fif
mnStim1.fif
mnStim150.fif_out.fif
out_trig1_mnStim150.fif
out_trig2_mnStim150.fif
mnStim2.fif
out_ASD_mnStim150.fif

All Outputs in current directory

out_trig1_mnStim150.fif.mat
out_trig1_mnStim150.fif
out_trig2_mnStim150.fif.mat
out_trig2_mnStim150.fif
out_trace_trig1_sensor1_mnStim150.fif.mat
out_ASD_mnStim150.fif
out_tfr_trig1_sensor1_mnStim150.fif.mat
out_trace_trig2_sensor1_mnStim150.fif.mat

Figure 2: The output data file in the current directory are grouped into the type of analysis performed.



Initialization Parameters For Analysis

Using parameter file: InitParamNEUROMAG306.txt

Sensor File: loc306.txt

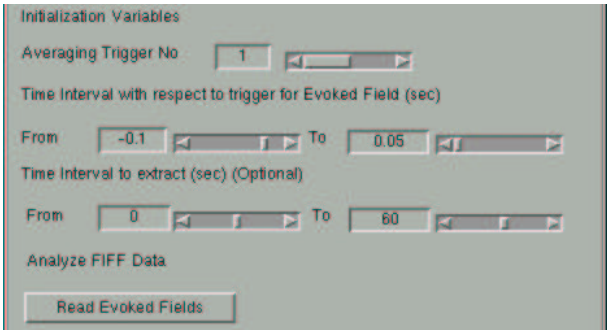
EOG Reject Threshold (p2p) uV: 15000

Jump In Field Threshold (fT/cm/s): 1e+06

Max. Field Reject (fT/cm): 3e+06

Stimulus Delay: 0

Figure 3: The parameters which define the threshold setting for the sensor rejection.



Initialization Variables

Averaging Trigger No 1

Time Interval with respect to trigger for Evoked Field (sec)

From -0.1 To 0.05

Time Interval to extract (sec) (Optional)

From 0 To 60

Analyze FIFF Data

Figure 4: The part of the main window which EF's are calculated.

8 Evoked Fields(EF)

8.1 Calculating Evoked Fields(EF)

The evoked fields are calculated from part 2 of the main window of D4D Figure 4.

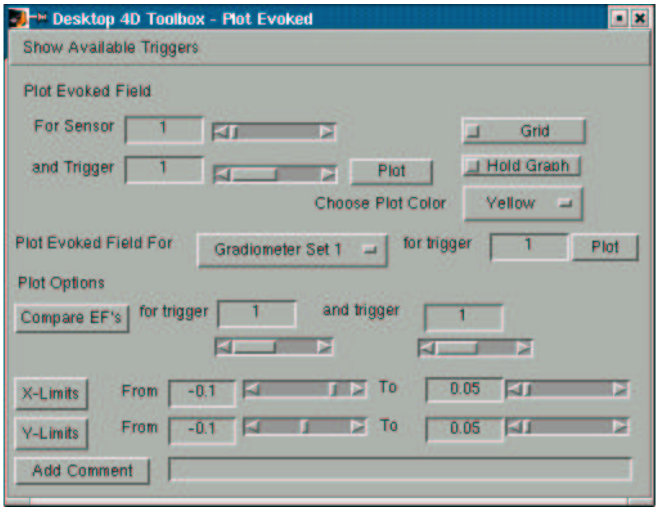
The input parameters in this case are duration which EF's will be calculated, the first being pre-stimulus interval and second the duration after the trigger and the trigger number which the EF's will be calculated.

After choosing the duration and the trigger press the *Read Evoked Fields*, the extraction will begin with an indicator showing the approximate duration to finish.

It is inevitable that some of the sensor traces are rejected due to high noise in that particular channel. Although there is a part in the main windows where these channels can be viewed the version 1.0 does not support this. However these bad channels can be observed from the command line output on the Matlab command window. After identifying the bad channel number, the *Mark* button can be used.

8.2 Viewing Evoked Fields(EF)

After the calculation, the EF's can be viewed from the menu item *Plot Data* ↪ *Plot Evoked Response*. The new window (Figure 5) now shows the viewing options and parameters. Either single sensor fields or EF for all the sensors can be viewed.
Comparison of EF's with respect to different triggers are possible using the *Compare EF's* option. An example output of the evoked field can be seen on Figure 6.



Desktop 4D Toolbox - Plot Evoked

Plot Evoked Field

For Sensor: 1

and Trigger: 1

Choose Plot Color: Yellow

Plot Evoked Field For: Gradiometer Set 1, for trigger: 1

Compare EF's for trigger: 1, and trigger: 1

X-Limits From: -0.1 To: 0.05

Y-Limits From: -0.1 To: 0.05

Figure 5: EF plot window.

The D4D allows multiple EF's to be plotted on the same graph for comparison with different colors using the Hold Plot and Plot Color options on Plot Evoked Response window (Figure 5)

9 Sensor Traces

9.1 Extracting Sensor Traces

Extraction of traces for one or all channels is possible from the part 3 of the main window shown in Figure 7.
The trigger to which the traces could be extracted and the sensor can be selected.

9.2 Viewing Sensor Traces

The traces can be viewed from the menu item *Plot Data* ↪ *Plot Trace*. The window shown in Figure 8 now shows the viewing options. There are also two preprocessing options present, which are *Subtract Baseline* and *Apply Smoothing*. The *Subtract Baseline* subtracts a baseline between the two time parameters given in *seconds* from the averaged traces. The *Apply Smoothing* button performs smoothing by Savitzky-Golay filtering using the given number trace width [1]. Refer to [1] and [2] for more information about this parameter.

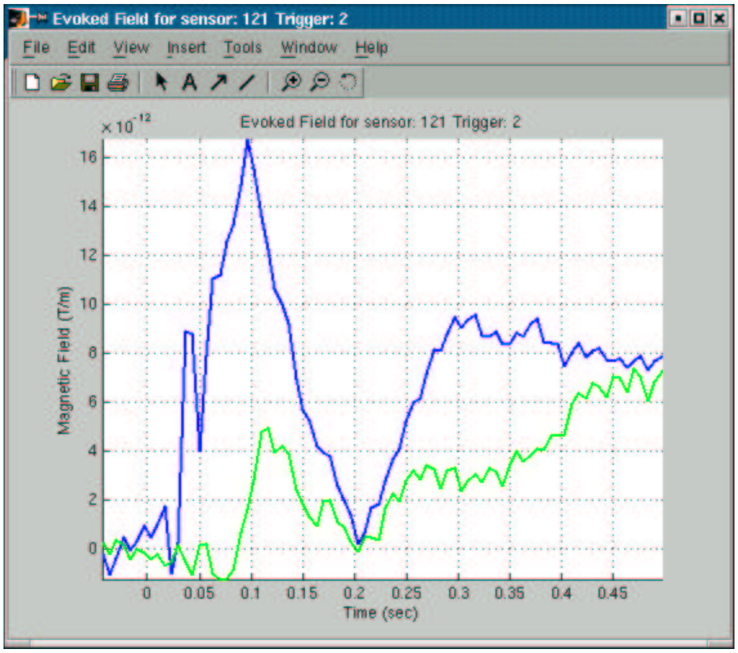


Figure 6: The results of the EF analysis can be quickly observed. Here the graph in blue shows the EF for Sensor 121 for Trigger 1 and the green graph shows the EF for the Sensor 121 for Trigger 2.

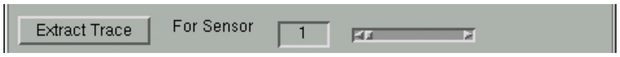
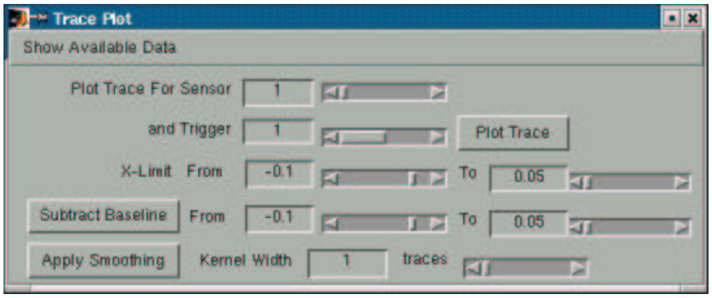


Figure 7: The part of the main window where sensor trace extraction parameter is set. In addition to this, the trigger is selected from part 2 of the main window shown in Figure 4



Plot Trace For Sensor 1

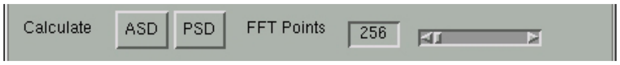
and Trigger 1

X-Limit From -0.1 To 0.05

From -0.1 To 0.05

Kernel Width 1 traces

Figure 8: The results of the Trace analysis can be quickly plotted using the *Plot Trace* menu option from the main window.



FFT Points 256

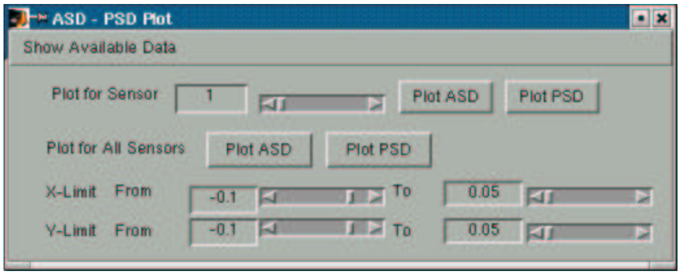
Figure 9: The Amplitude Spectral Density (ASD) and Power Spectral Density (PSD) can be calculated from the part 4 of the main window.

10 Frequency Analysis: Power and Amplitude Spectra

10.1 Calculating Power and Amplitude Spectral Density (ASD)

The power and amplitude spectral density (ASD) of a data set can be calculated using part 4 of the main window shown in Figure 9 with *Calculate ASD* and *Calculate PSD*. The functions are based on Welch's method for applying data windowing and fast-fourier transform (FFT) [1].

The ASD's are calculated are calculated irrespective of the triggers and the default number of points used in the FFT algorithm is `nfft=256` [1]. The ASD's are calculated using Welch's method: the time is subdivided into windows of length `nfft` with 50% overlaps. Each subtrace is then detrended and multiplied to a Hanning window and then the absolute values of the Fourier transformed windows are averaged [1, 3]. The `nfft` determines the frequency resolution of the ASD. A larger value for `nfft` results in more narrow spectral peaks but a more noisy base level, a smaller value lowers the noise of the base level, but broadens the spectral peaks [1].
The power spectral density (PSD) is also calculated using *Calculate PSD* button.



Plot for Sensor 1

X-Limit From -0.1 To 0.05

Y-Limit From -0.1 To 0.05

Figure 10: The results of the Frequency analysis can be quickly plotted using the *Plot ASD-PSD* menu option from the main window.

10.2 Viewing Power and Amplitude Spectra

The results of the ASD and PSD calculation can be viewed from the menu item *Plot Data* ↪ *Plot ASD and PSD*. The window (Figure 10) shows the viewing options.

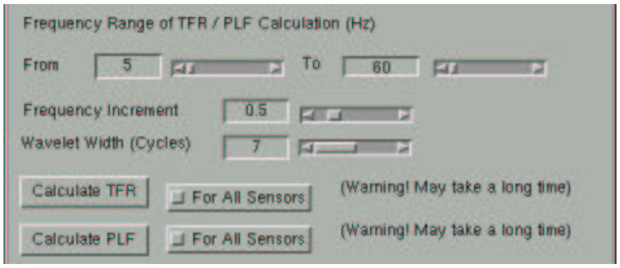
The ASD and PSD can be plotted for a single sensor or for the whole set of sensors.
Note that the ASD's for the gradiometers with the same location but orthogonal orientations are averaged. The division of the sensors into 3 sets is done the same way as viewing the Evoked Fields [1].

11 Time Frequency Representations(TFR) Using Wavelets

TFR's are used to study how oscillatory signals evolve over time and with TFR it is possible to calculate and visualize a broad range of frequencies simultaneously [1].
The TFR's are calculated using a method based on Morlet wavelets: for a given time and frequency a Morlet Wavelet is convolved to the data. The squared absolute value is the energy (*power*) of the signal and the *width* of the wavelet determines the time and frequency resolution [1, 4, 5].

11.1 Calculating TFR for Single Sensor Data

TFR's for multiple traces extracted with respect to a trigger, can be calculated and averaged using part 5 of the main window shown in Figure 11.
The parameters to be adjusted here are the Frequency Range and the frequency increments of the TFR calculation. The width(in cycles) of the wavelet used can be adjusted. If the value is increased the frequency resolution becomes better, but the time resolution is worse and vice versa and it is



Frequency Range of TFR / PLF Calculation (Hz)

From 5 To 60

Frequency Increment 0.5

Wavelet Width (Cycles) 7

Calculate TFR
For All Sensors
(Warning! May take a long time)
Calculate PLF
For All Sensors
(Warning! May take a long time)

Figure 11: Time Frequency Representations(TFR), can be calculated from the part 5 of the main window. In addition to this, the trigger and time interval with respect to the trigger (pre and post) is adjusted from Figure 4

not recommended to use a value less than 5 as stated in [1]. The time interval with respect to the trigger (pre and post) for which TFR's are calculated can be adjusted from Figure 4

11.2 Calculating TFR for All Sensors

The TFR for all sensors can be calculated for all sensors using the *For All Sensors* switch in Figure 11 in the main window. The same parameters are used for calculating the Single Sensor TFR calculation. The time interval with respect to the trigger (pre and post) for which TFR's are calculated can be adjusted from Figure 4

11.3 Viewing TFRs

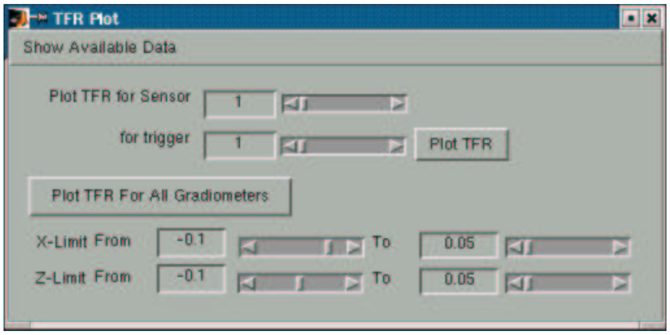
The results of the TFR calculation can be viewed from the menu item *Plot Data* ↪ *Plot TFR*. The window in Figure 12 shows the viewing options.

The TFR can be plotted for a single sensor or for the whole set of sensors. The TFR for gradiometers which have the same location but orthogonal orientation are averaged in the same graph. The minimum and maximum energy together with `z-limits` can be set.

12 Phase Locking Factor (PLF)

12.1 Calculating the PLF

The Phase Locking Factor-PLF is a tool for characterizing evoked activity, phase locked to the stimuli [1, 6]. For a sensor or a set of sensors, the PLF can be calculated from the traces extracted. The absolute value, abs(PLF), yields a number between 0 and 1 determining the degree of phase locking.



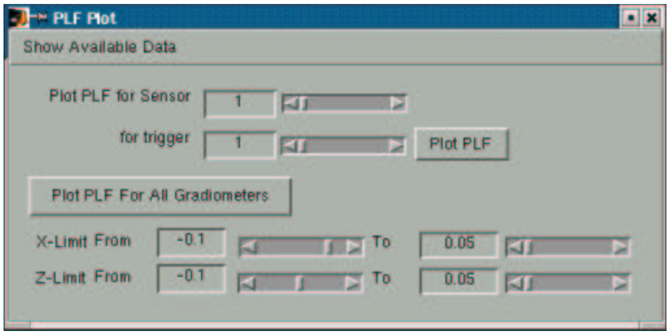
Plot TFR for Sensor 1

for trigger 1

X-Limit From -0.1 To 0.05

Z-Limit From -0.1 To 0.05

Figure 12: The results of the TFR analysis can be quickly plotted using the *Plot TFR* menu option from the main window.



Plot PLF for Sensor 1

for trigger 1

X-Limit From -0.1 To 0.05

Z-Limit From -0.1 To 0.05

Figure 13: The results of the PLF analysis can be quickly plotted using the *Plot PLF* menu option from the main window.

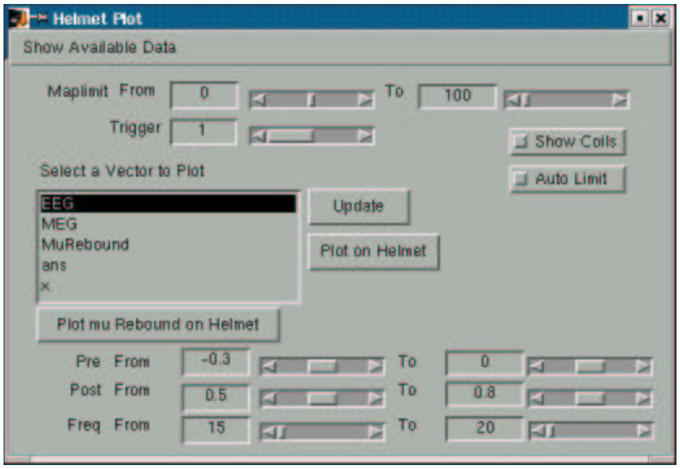
Phase Locking Factor(PLF), can be calculated from the part 5 of the main window(see Figure 11). In addition to this, the trigger and time interval with respect to the trigger (pre and post) is adjusted from part 2 of the main window (see Figure 4).

12.2 Viewing the PLF Calculation

The results of the phase locking factor can be plotted using the *Plot PLF* selection from the main menu. Figure 13 shows the plotting window.

13 Topographical Color Plots on Neuromag Helmet

Mentioned in [1] these kind of plots are useful when studying the spatial distribution of a processed signal.



Maplimit From 0 To 100

Trigger 1

□ Show Coils

□ Auto Limit

Pre From -0.3 To 0

Post From 0.5 To 0.8

Freq From 15 To 20

Figure 14: The Neuromag helmet plotting window

The Neuromag helmet plots can be displayed using the menu item *Plot Data* ↪ *Plot Neuromag Helmet*. The window in Figure 14 shows the viewing options and Figure 15 shows a result of the output.

The colored helmet plotting can be done for a 61-element or 122-element vector on the workspace. The workspace variables can be seen in the selection box. Press the *Update* button to refresh the selection box and view the latest variables on the desktop. By pressing the *Plot Helmet* button the vector is plotted on the Neuromag Helmet.

As an exemplary case ”the relative rebound of the mu-rhythm” can be calculated using the parameters on the bottom of the window. The parameters to be adjusted are the Frequency band, Time Interval for the energy to be calculated and the time interval preceding the stimuli [1].

14 Post Processing Functions

Some post processing functions for analyzed data can be applied using the Postprocess window shown in Figure 16. This window can be accessed from the *Postprocess* menu item from the main window.

To apply filters to the data;

1. Load data to the workspace by pressing *Load Data*or press *Update*

2. Choose the data vector or matrix from the listbox

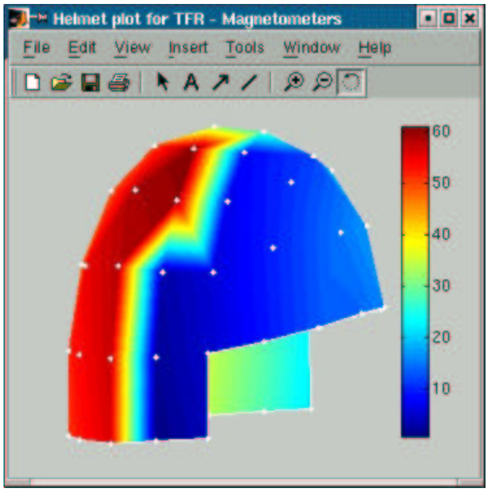


Figure 15: The plot of the helmet for a signal vector with either 61 or 102 elements

3. Enter the necessary parameters for the chosen filter and apply.

The functions in this window (Figure 16 can apply the following filters [1]:

FFT Bandpass Filter An acausal (zero phase shift) FFT Bandpass filter. Filter function is constructed using a Hamming window [1, 2]

FFT Lowpass Filter An acausal (zero phase shift) FFT Lowpass filter. Filter function is constructed using a Hamming window [1, 2]

FFT 50Hz Notch An acausal (zero phase shift) 50Hz notch filter [1].

Line Noise Reduction(50 Hz) Filter The amplitude and phase of the line noise is estimated. A sinusoid with these characteristics is then subtracted from the signal [1].

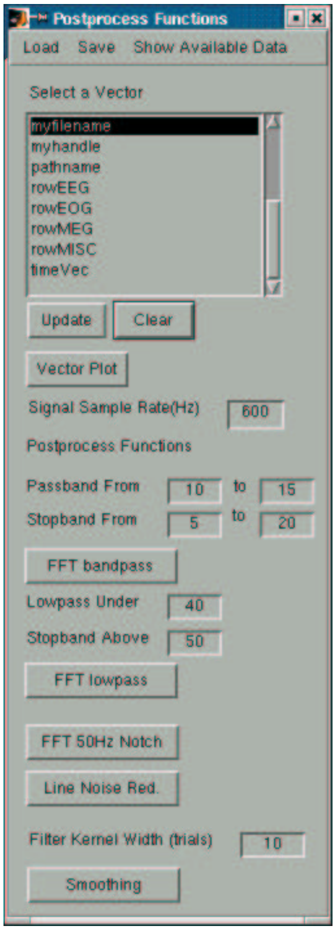
Smoothing Smooths a data array using Savitzky-Golay filtering [1].

References

[1] O. Jensen. 4-D Toolbox v1.2 Manual, 2001

[2] W.H. Press, S.A. Teukolsky, W.T Vetterling and B.P. Flannery. Numerical Recipes in C. Cambridge University Press, USA, 1997

[3] E.C Ifeachor and B. W. Jervis. Digital Signal Processing. A Practical Approach. Addison-Wesley, 1993.



Signal Sample Rate(Hz) 600

Passband From 10 to 15

Stopband From 5 to 20

Lowpass Under 40

Stopband Above 50

Filter Kernel Width (trials) 10

Figure 16: Some post-processing functions can be applied to the data currently on the workspace

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