**MATLAB Application BRAD: Documentation**

The application allows to upload the BOLD-signal, filter it from the white noise if necessary, and estimate the underlying neuronal activity signal.

**1. Import data**

The **panel "Import data"** should be used for uploading data. There should be uploaded the measured BOLD-signal and haemodynamic response function (HRF).

"Import data" button allows uploading ".csv" file with the input signal. The file should contain one time series which is supposed to be measured BOLD-signal.

"Import HRF" button should be used for uploading the form of the haemodynamic response function. It is assumed that the sampling rate of the input signal is equal to the sampling rate of HRF.

The checkbox "Use default kernel" allows to generate haemodynamic response function by the function spm\_hfr with the predefined scan repeat time (RT). Its default value is 2.5s, but it easily can be changed by user.

*Technical details.*

"Import data" button: BOLD-signal is a numerical column vector Nx1 which is saved in ".csv" file.

"Import HRf" button: ".csv" file should contain the numerical column vector Mx1. It should be shorter than the input signal.

Data should be encoded in ASCII standard; as a decimal separator should be used dot (.), no digit grouping is assumed, leading negative sign (-) is used for negative numbers indication, optional leading sign (+) can be used for positive numbers indication.

The MATLAB command *csvwrite(‘filename.csv', variableName)* can be used for creating an appropriate file.

**Panel "Load"**. Also, the panel "Load" can be used for importing earlier saved data and application settings. The button "Load input settings" load the input signal, haemodynamic response function and the spectrum (if needed).

The button "Load calculations" can be used for uploading calculations which were saved before. The input settings should correspond to the loaded calculations.

**2. Calculations**

After downloading the input data it is necessary to configure the **panel "Calculations"**. It contains 3 deconvolution methods and 2 possibilities for the signal (original and filtered). The user should choose what deconvolution methods are interesting for him. Also, the user should specify if he/she is interested in filtered or/and not filtered signal.

In case of changing any of previous information (importing another data, choosing another filtering option) the calculation should be repeated.

**3. Filtering of the signal**

The application allows reducing the white noise by filtering the input signal. **Panel "Filtering of the signal"** can be used for it. It contains three possibilities: to use the default spectrum, to use the input BOLD-signal for estimating the spectrum and to upload user's spectrum.

The default spectrum is generated using saved parameters (Input/Spectrum/defaultParameters.mat) and shape of the uploaded kernel (HRF). Fitting the spectrum from the data uses the same approach as the previous option, but use the parameters obtained from the input signal. The option "Load user's spectrum" allows uploading user's power spectrum after pressing "Calculate" button. User's spectrum should be the numerical non-negative column-vector which has the same dimension as the input signal.

**4. Save**

The **panel "Save"** allows to save input settings, all calculations and estimated (deconvolved) signal. Saved data can be later used for uploading.

**5. The chart**

The input signal and estimate of the neuronal signal are shown on the chart in blue and red color respectively. BOLD-signal appears after uploading the data. Estimate of the neuronal signal appears after choosing the deconvolution method on the panel "Deconvolution methods". BOLD-signal can be filtered or not filtered depends on the option on the panel "Signal Type". BOLD-signal is rescaled after uploading to have range [0,1].

Chart title contains details about the estimated neuronal signal. It consists of the name of used deconvolution method, information whether filtered or original input signal was used, selection criteria and the number of non-zero peaks in the estimate.

**6. Signal Type**

The **panel "Signal Type"** contains options for the input signal. If "Original signal" option is chosen then the estimate will be shown for the not-filtered signal. If "Filtered signal" option is chosen then filtered signal will be used.

**7. Deconvolution methods**

The **panel "Deconvolution methods"** is intended for working with different methods of neuronal signal estimation. Three methods are presented on the panel.

Few selection criteria are proposed for each of deconvolution methods. For all of them it is possible to choose “All peaks”, which gives the estimates contained maximum peaks for each method, and “Known Peaks Amount”, where the user can set the need number of non-zero peaks in the estimate.

For DS and LASSO also possible: AIC, BIC and MIC (Mixture Criterion, the selection criteria developed by our group).

*Remark:*

* In Dantzig Selector method the maximum iteration parameter is used. Its default value is length of the input signal times 4. However, in case is not enough, the estimate for “All peaks” will contain not all peaks. In this case it is possible to set bigger maximum of iterations *(Functions/Deconvolution/usualParameters.m parameter.constIteration = …).*
* In case of singular (or close to singular) Toeplitz matrix constructed from the HRF, for OLS estimate the lasso method is used with parameter ‘Lambda’ equal to 0.

**8. Movie**

The **panel "Movie"** can be used (optionally) for additional analysis of the signal. The movie can be imported and a few possibilities to use it are implemented.

The **panel "Import movie data"** contains two possibilities to load frames from the movie. The collection of frames can be directly uploaded using the button "Import frames". File should contain the cell array named "frames". Each cell should contain three 2D-numerical matrices describes pixels in the movie frames. Another possibility to load the movie information is to load the movie and exact frames from it. The button "Import movie, exact frames" should be used for it. The movie format should be ".mp4". The procedure of exacting frames from the movie can take a lot of time.

**Frames Rate.** The rate of frames is needed for correct working with movie material. Frame rate should be set in seconds. Its default value is 2.5 seconds. It means that uploaded collection of frames should contain frames with timing 0s, 2.5s, 5s, 7.5s, so on. If the movie is uploaded then frames will be exacted with the specified frames rate.

**Sampling Rate.** The sampling rate is used for building the correct correspondence between measured signal and collection of frames. It should be set in seconds and it should correspond to the loaded input data (BOLD-signal).

The **panel "Show frames"** is used for the analysis of the estimated neuronal signal.

"Show the current frame" button shows the frame corresponds to the Data Cursor. "Show the current and the previous frame" button shows the frame corresponds to the Data Cursor and the previous one (according to the frames rate). "Show frames for the positive peaks" button shows the collection of frames corresponding to all positive peaks in current estimate of the neuronal signal.

The **panel "Show particular frame"** allows showing the frame corresponds to the needed point in the signal (field "Point") or to the time point in seconds (field "Second"). Fields "Point" and "Second" are connected using sampling and frames rates, thus it is enough to change one of them.

The **panel "Show frames for the period"** allows to show frames from the period specified using fields "From" and "To" which should be specified in points as well as the measured signal.

ADDITIONAL:

The **button “Whole Brain Level”** works with voxels level. Dantzig Selector and LASSO are available as deconvolution methods. Available selection criteria are: MIC, AIC, BIC and All peaks. In case of “All peaks” the output will be equal to OLS estimate.

Input: both voxels-level data and gray-matter mask should be uploaded in ‘.nii’ format. HRF can be uploaded as the ‘.csv’ file, or can be generated using the function spm\_hrf using the appropriate RT.

Calculations will be made for voxels, which gray-matter mask value is not zero.

After the calculations (which can take a long time) the user should choose where to save the result (‘.nii’-file).

**Examples.**

Two time series are saved in "Input/Time series/" as the examples of the input signal (Checkerboard.csv and western.csv).

Two input settings collections and corresponding calculation collections are available as the example. Examples of input settings and calculations are located in “Saved settings”.

The user spectrum for the western data is saved at “Input/Spectrum/spectra\_121\_1.csv”.

*Last change: 31th of August 2017 by Anna Pidnebesna.*

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