SSS-Beamformer – short summary

The idea of SSS-Beamformer is that beamforming is done in SSS basis space rather than channel space. This can have several advantages:

1) A good way to combine the two sensor types
2) A good way to reduce data dimensionality preserving most of the brain signals.
3) It's possible to combine bits of data with different bad channels, different head locations etc.

TSSS toolbox for SPM12 provides GUI-based tools for accessing TSSS Matlab functions originally written by Samu Taulu and apply TSSS to datasets in SPM format.

A key thing to understand is that the SSS basis is complex. This makes it difficult to process the data in SPM because SPM binary file format does not support complex numbers. The workaround is to use 'virtual montage' functionality in SPM12. The complex channel2SSS transform matrix is stored in the header and applied on the fly transparently for the user. The data are still stored on disk as 306 channels. Therefore, the same dataset can either appear to have 306 (or more) channels with real data (montage not engaged) or a much smaller number of channels with complex data (it is also possible to add additional channels to the montage (e.g. to use as the reference in DICS).

Normal SPM operations like reviewing, filtering or artifact detection are only possible when the montage is not engaged. For SSS beamforming the montage should be engaged.

The second important point is that usually SSS basis is still rank-deficient and will not produce good beamforming results. A further regularization step is necessary and the paper recommends removing the basis vectors one by one to find the ones that reduce the condition number (ratio of larges to the smallest eigenvalue) of the covariance matrix the most at each step. This is repeated until the condition number drops below a pre-defined threshold. This step can be performed separately, using a pre-computed SSS basis. The original number of SSS basis vectors depends on the 'Inner dimension' parameter. The regularization further reduces it and the lower the threshold the fewer vectors will be kept.

The third point is that the SPM version of TSSS can use the information about bad channels and samples stored in the dataset. It is possible to scan the data for artefacts prior to SSS using different techniques and mark the bad segments (see 'Advanced topics in artifact removal' chapter in SPM12 manual). The TSSS tool uses this information by doing TSSS in short windows and for each window excluding channels where there are bad samples in that window. So it is possible to have a channel where only part of the data are bad. The TSSS code itself does

not detect artefacts or mark bad channels. This should be done as a separate step.

The spatial projection in SSS does not depend on the channel data, only on the head location. So SSS transform will still be valid if the data are further processed (e.g. filtered or downsampled) after the TSSS step.

A typical TSSS pipeline in SPM will thus look as follows.

1) Conversion from fif to SPM format. Important: 'Save original header' should be set to 'Yes' for TSSS. It's not by default.
2) Some preprocessing steps (e.g. filtering).
3) Artefact detection if necessary. ('Mark' mode in the artifact tool, see manual chapter).
4) TSSS denoising tool. I won't explain the parameters as they are the same as in MaxFilter. When 'Output space' is 'sensor' the SSS montage will not be engaged in the output dataset.
5) Some further processing if necessary: epoching etc.
6) 'TSSS space conversion'. One can play with different threshold values here without re-doing TSSS. Form our limited experience numbers between 50 and 100 give comparable results.
7) DAiSS analysis. Important: Head model must be re-specified when switching from sensor to SSS space or when changing the condition number threshold. 'Modalities' in the 'Covariance features' and 'Output' module must be set to 'MEG'. No further regularization is necessary so 'User-specified regularisation' with the value of 0 should be used.

TSSS can be combined with any of the example pipelines available in the DAiSS folder. The settings might have to be modified as above.

A way to switch from SSS back to channel space in the GUI is to use the 'Montage' tool. 'Mode'<-'Switch', 'Montage specification'<-'Montage index'<-0.

From the command line:

D = spm_eeg_load
D = montage(D, 'switch', 0); % to sensor space
D = montage(D, 'switch', 1); % to SSS space
save(D);